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#215 APRIL 2023

Sky at Night

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MISSION TO THE ICY MOONS

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Welcome

JUICE – our best chance to find life beyond Earth?

Decades in the planning, ESA's Jupiter Icy Moons Explorer (JUICE for short) is scheduled for launch this April. It's the first of Europe's three planned L-class missions, the largest and most costly class of campaign in Europe's long-term plan for space exploration. We're excited to be covering the mission on **page 28**, where Will Gater explores the spacecraft and its science goals, which include investigating whether conditions could be favourable for life under the thick ice crusts of Callisto, Ganymede and Europa.

Jupiter isn't visible in April (it's hidden in the Sun's glare), but for planetary observers it's all about Mercury this month. An elusive world that stays close to our central star in the sky, this month sees it reach its furthest distance from the Sun, setting two hours after sunset and visible in the evening. It's the best chance this year of seeing the innermost planet, so turn to Charlotte Daniel's observing guide on **page 34** to make the most of it! Then turn to the Sky Guide from **page 43** for the many other stargazing delights the night sky has in store for us in April – meteor showers, delightful conjunctions and star clusters included.

Also this month, many will be pleased to hear that *The Sky at Night* team returns to our screens on BBC Four on 10 April. Maggie, Chris and Pete will be looking at JUICE and other missions that are furthering our understanding of where alien life could exist. Turn to **page 18** for more details.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 20 April.

HOW TO CONTACT US

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

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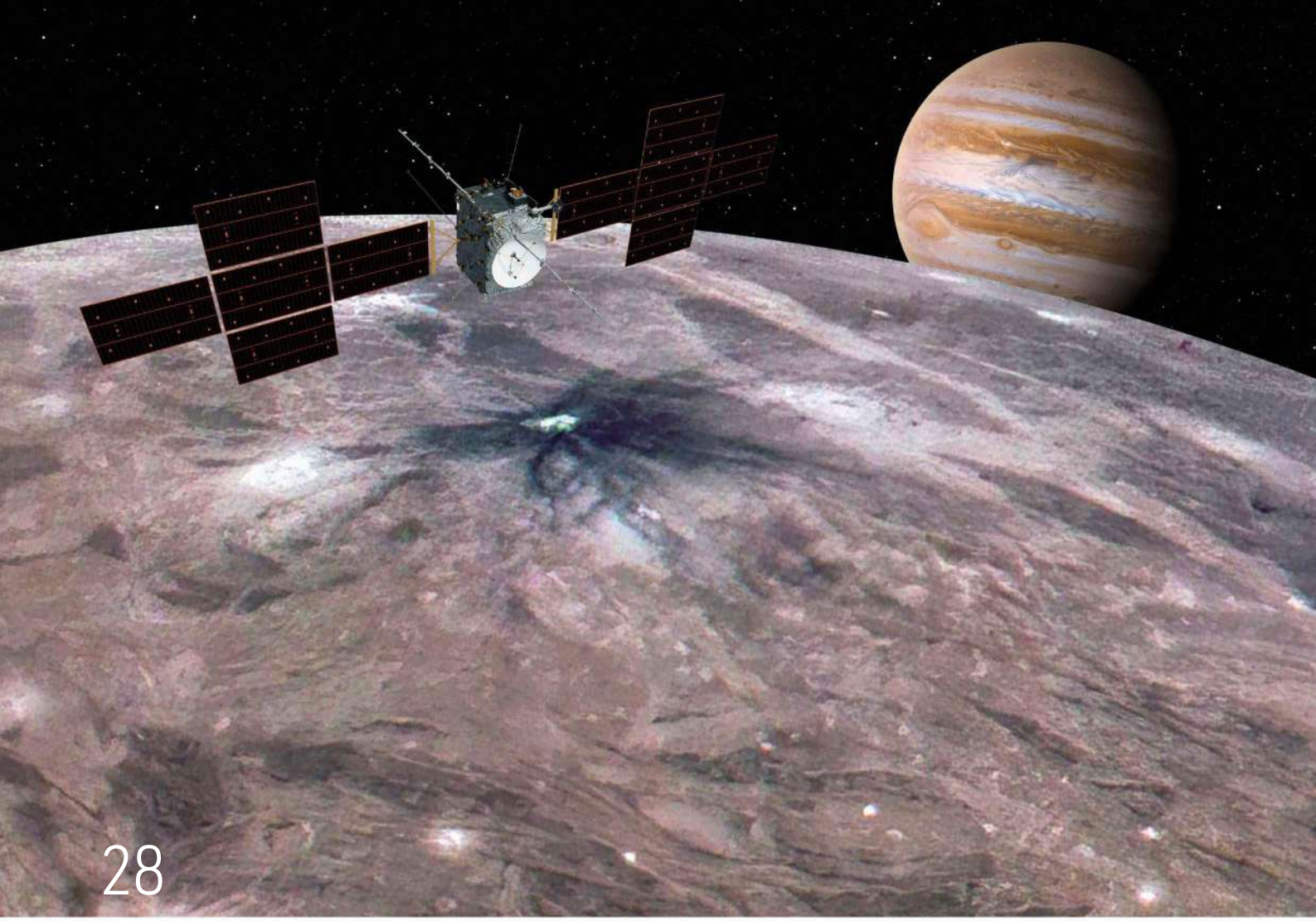

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The Sky Guide

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New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

This month's contributors

Will Gater

Astronomy expert

"It'll be a while before JUICE arrives at Jupiter, but I genuinely can't wait to see what the mission has to tell us about the incredible icy worlds that orbit the giant of our Solar System". **Read more about JUICE,** page 28

Charlotte Daniels

Practical astonomer

"Oft-overlooked, Mercury will be a great target to observe in the evening twilight in April. I'm looking forward to exploring the inner planet this month." **Charlotte reveals how to make the most of Mercury,** page 34

Shaoni Bhattacharya

Science journalist

"The number of satellites going into space in the near future is staggering, and this was a topic of great discussion at the Abu Dhabi Space Debate." **Hear more about the international debate,** page 60

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/9BN84GZ** to access this month's selection of exclusive Bonus Content

APRIL HIGHLIGHTS

Black holes and bending spacetime

Luciano Rezzolla discusses the mind-blowing properties of gravity and his quest to understand black holes

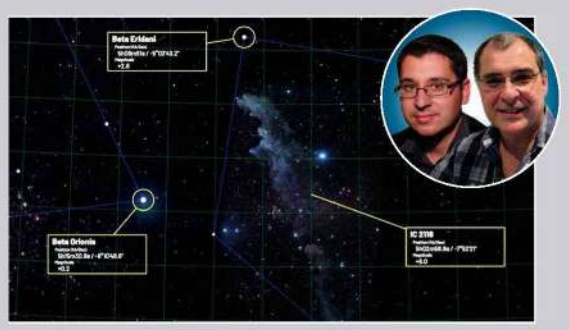
Download automated telescope software

Slew your telescope instantly to each target in this month's Deep-Sky Tour with our selection of automated software.

Access extra observing materials

Download and print out forms that you can use to sketch and record your planetary observations throughout 2023.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

SERENE SHINING STARS

A moment of calm in a tumultuous Universe

HUBBLE SPACE TELESCOPE, 23 JANUARY 2023

Space is filled with violence. Gigantic explosions, temperatures both incredibly hot and unimaginably cold, forces strong enough to tear stars apart. Yet sometimes it can appear peaceful and serene, as this photo of stars piercing the dust and gas of the Orion Nebula 1,450 lightyears from Earth shows.

It's a deceptively beautiful image, however. The main star, V 372 Orionis, is an Orion Variable, a young star prone to sudden variations in luminosity with no pattern or schedule. These stars are often found in the kind of diffuse nebulae Orion is famous for, and are expected to grow out of their variability as they age.

Also visible in the image are the signatures of Hubble, the four diffraction spikes caused by starlight interacting with the four vanes that support the telescope's secondary mirror.

MORE **ONLINE**

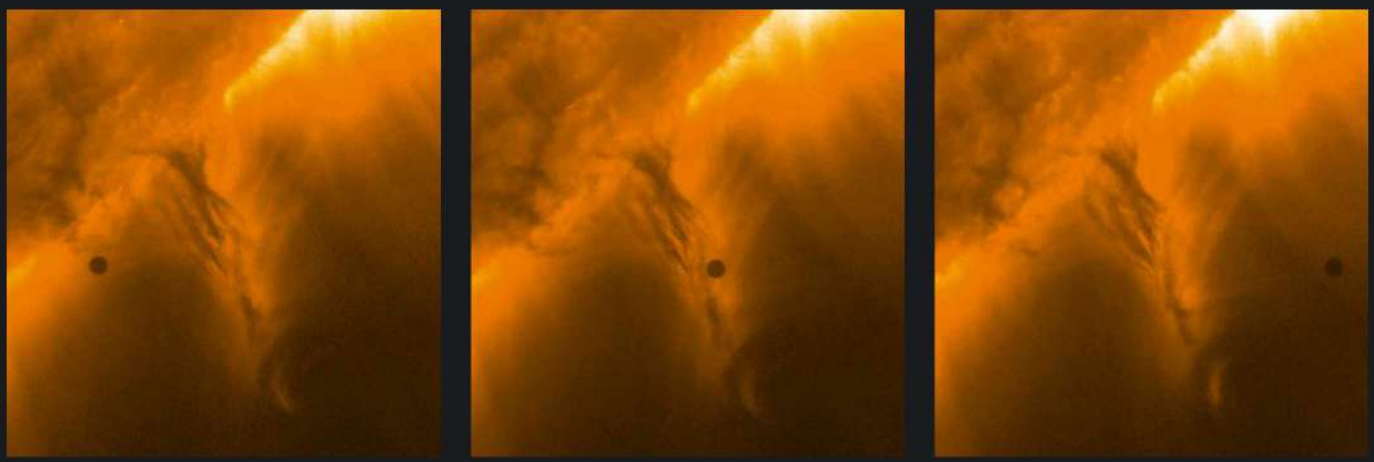
Explore a gallery of these and more stunning space images

ESA/HUBBLE & NASA/J. BALLY/M. ROBBERTO

◁ Bear rock

MARS RECONNAISSANCE ORBITER, 25 JANUARY 2023

The Moon may have a man in it, but Mars has a bear. This example of pareidolia – the tendency of the human brain to see faces in things – joins the famous 'face' in the planet's Cydonia region. The bear's nose is a hill, perhaps a volcanic vent, that's collapsed, creating a distinctive shape joined by two impact craters forming the bear's eyes. A circular fracture pattern outlining what could be another buried crater provides the finishing touch.



△ Mass transit

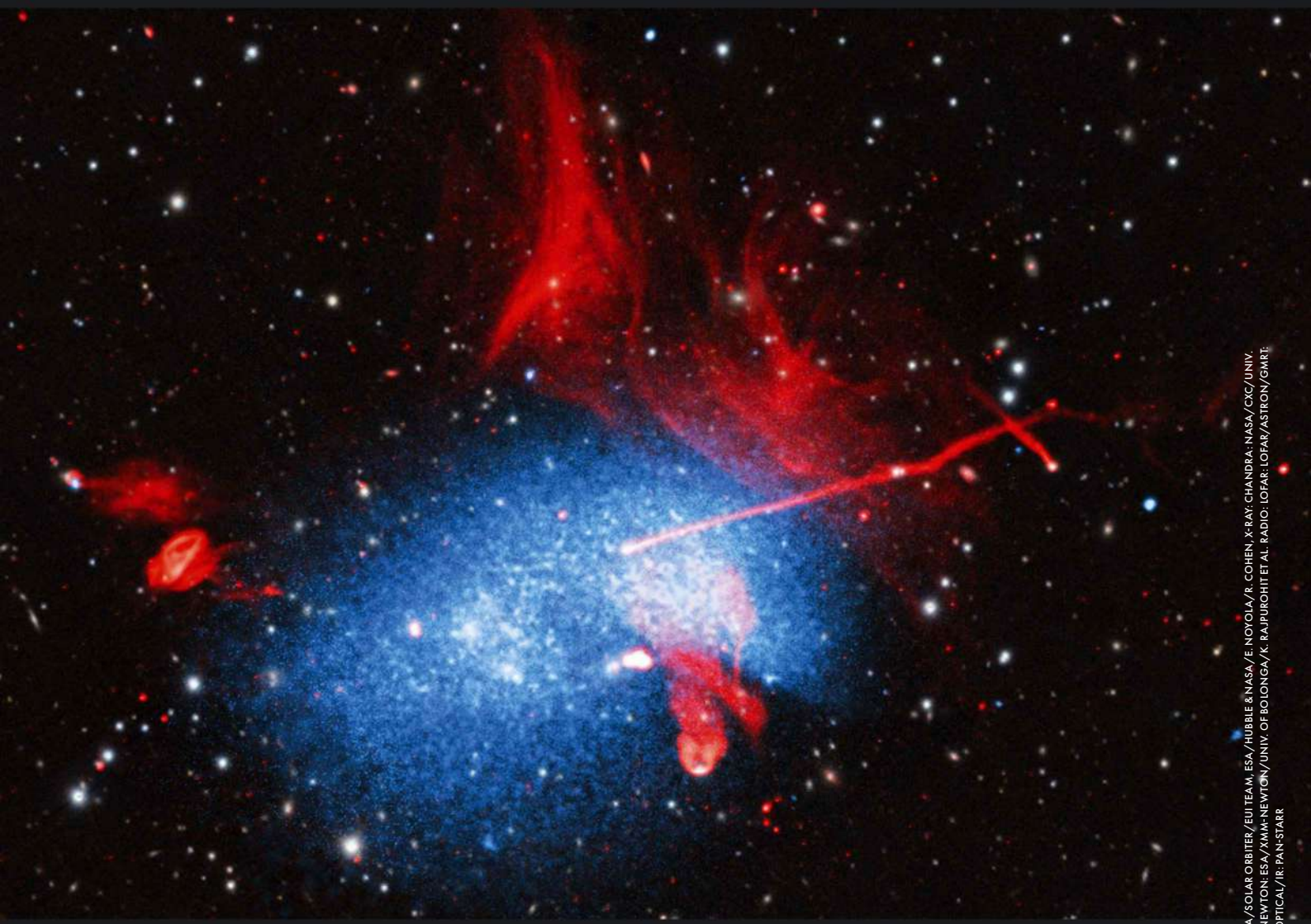
SOLAR ORBITER, 3 JANUARY 2023

Mercury passes in front of the Sun, showing the sheer scale of our host star. The planet is 5,000km across, yet is dwarfed by the towering structures in the Sun's outer atmosphere. These video stills were captured by the Extreme Ultraviolet Imager on board ESA/NASA's Solar Orbiter spacecraft and show solar atmospheric layers above the photosphere, the star's outer shell from which its light radiates. You can watch the full video at **bit.ly/mercurytransitvideo**.

Cluster of gems ▷

HUBBLE SPACE TELESCOPE, 2 JANUARY 2023

Hubble's Advanced Camera for Surveys and Wide Field Camera 3 continue to deliver remarkable images, such as this shot of the tightly packed core of the globular cluster NGC 6355. The cluster resides toward the centre of the Milky Way, around 30,000 lightyears from Earth in the constellation Ophiuchus, contains over 100,000 solar masses, and is estimated to be 13.2 billion years old.



NASA/JPL-CALTECH/UARIZONA, ESA & NASA/SOLAR ORBITER/EUI TEAM, ESA/HUBBLE & NASA/E. NOYOLA/R. COHEN, X-RAY: CHANDRA: NASA/CXC/UNIV. OF BOLONGA/K. RAJPUROHIT ET AL/ XMM-NEWTON: ESA/XMM-NEWTON/UNIV. OF BOLONGA/K. RAJPUROHIT ET AL. RADIO: LOFAR: LOFAR/ASTRON/GMRT: NCRA/TIFR/GMRT/VLA: NSF/NRAO/VLA/OPTICAL/IR: PAN-STARR

△ Collision course

CHANDRA X-RAY OBSERVATORY, XMM-NEWTON, LOW-FREQUENCY ARRAY, GIANT METREWAVE RADIO TELESCOPE, VERY LARGE ARRAY, 30 JANUARY 2023

Some of the largest structures in the Universe are crashing together to create Abell 2256, a merger of at least three galaxy clusters in Ursa Minor. It took five telescopes recording data from radio waves, X-rays, visible and infrared light to create this image, with hot gas glowing blue in X-rays at the bottom, while red data from radio waves shows jets from supermassive black holes and shock waves at the top that stretch for two million lightyears.

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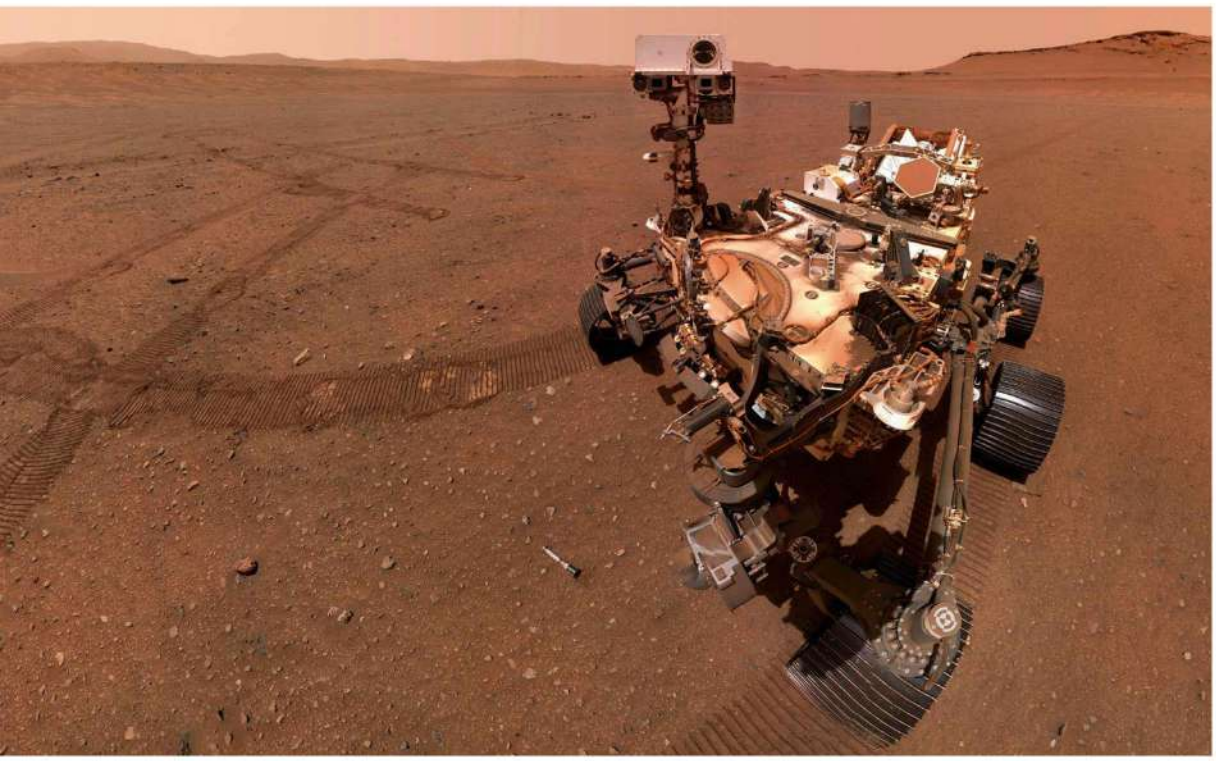


▲ The location of the tubes has been carefully mapped so they can be found even if covered with dust

NASA/JPL-CALTECH/MSSS

Perseverance's pick-up point

Sample tubes have been gathered on the surface for future collection

NASA's Perseverance rover has created its first depot of Martian soil samples, dropping its final tube on 29 January at a region known as Three Forks. A future joint NASA and ESA mission will aim to retrieve samples directly from Perseverance, but this depot will act as a back-up just in case the rover became inaccessible.

For the last three years, Perseverance has taken samples in pairs from across the surface – one to leave at the depot, one to keep on board. It has now collected nine rock and soil samples, as well as a 'witness tube' filled with Martian air that will help determine if the other tubes have been contaminated during their journey back to Earth.

Perseverance is exploring Jezero Crater, which was formed four billion years ago when conditions on Mars were temperate enough for liquid water to flow across the surface. The rover is traversing what was once a delta, where a river flowed out into a lake. This area offers a wide range of terrains, each shaped by different geological processes, that will give scientists insights into how water shaped the Martian surface. They may also contain signs of ancient microbial life.

The mission has already explored the lower parts of the delta, but has now transitioned to the top, a point marked by the 'Rocky Top' outcrop.

"We found that from the base of the delta up to the level where Rocky Top is located, the rocks appear to have been deposited in a lake environment," says Ken Farley, Perseverance's project scientist at Caltech. "Those just above Rocky Top appear to have been created in or at the end of a Martian river flowing into the lake.

"As we ascend the delta into a river setting, we expect to move into rocks that are composed of larger grains – from sand to large boulders. Those materials likely originated in rocks outside of Jezero, eroded and then washed into the crater."

mars.nasa.gov/mars2020

Comment

by Chris Lintott

The importance of getting fresh Martian material into a terrestrial laboratory can't be overstated. Though the instruments carried by rovers like Perseverance are wonders of miniaturisation, they can't possibly compete with the equipment sitting in any university lab.

Scientists around the world are already preparing their cases to be among the lucky few to get their hands on what's returned from Jezero Crater. Yet, just as we're still studying material brought back from the Moon by Apollo astronauts, NASA will set some precious Martian dust aside for study with technologies not yet developed. The researchers of a century hence may consider the contents of those tiny tubes even more special than we do.

Chris Lintott co-presents *The Sky at Night*

▲ **Coolant was seen pouring out of the Soyuz craft during a NASA live stream event in December. Watch the video at bit.ly/ISSleak**

Trouble at the ISS

Problems with two docked spacecraft could put future crew rotations in jeopardy

Two separate spacecraft docked with the International Space Station have suffered coolant leaks within two months of each other. One of the vehicles was intended to bring home three of the crew currently on board the station.

The first leak was detected on 14 December 2022 in the Russian Soyuz MS-22 capsule that delivered cosmonauts Sergey Prokopyev and Dmitri Petelin, along with NASA astronaut Frank Rubio to the station. While preparing for an evening spacewalk, station controllers discovered a stream of particles coming from the Soyuz. Deeming the spacewalk too dangerous with the leak, station controllers instead investigated the area with Canadarm2, a 17-metre-long robotic arm, discovering a hole in one of the coolant pipes. The Russian space agency, Roscosmos, reported that the damage was the result of a micrometeorite impact.

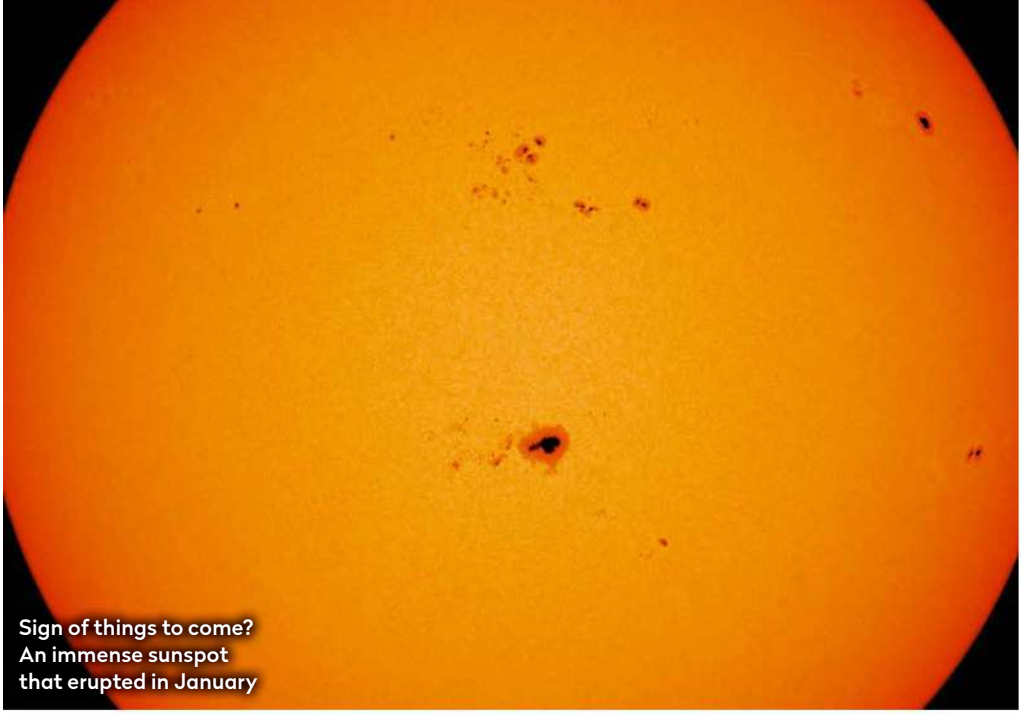
As they could not be certain that the damaged spacecraft was safe for human passengers, the agency began plans to launch an empty Soyuz MS-23 to the station, which the current crew could then use to return. MS-23 was initially meant to carry the next crew to the station in March 2023, and its repurposing could cause disruption to future crew rotations.

Then on 11 February, a second leak was discovered, this time on board the Progress 82 cargo spacecraft, also built by Roscosmos following a similar design to the Soyuz. Progress 82 has been docked with the station since October 2022, but suffered a depressurisation which was later linked to the ship's coolant system. Fortunately, the spacecraft was already scheduled to undock from the station on 17 February carrying trash rather than people, and so was able to depart as planned. The capsule spent several hours extra in orbit, allowing for a more thorough visual inspection from the ISS, but no obvious signs of damage could be seen as they had been on Soyuz MS-22. Progress 82 deorbited over the Pacific Ocean the next day.

Replacement crew capsule MS-23 was eventually docked on 25 February. Though the crew are not due to return to Earth until September 2023, the new Soyuz has already been reconfigured as the return vehicle, including transferring over each astronaut's custom-moulded seat liners, should the trio need to return to Earth in an emergency.

www.nasa.gov

NASA. NSAS/SDO, JAMES JOSEPHIDES/SWINBURNE UNIVERSITY, NASA/AMES RESEARCH CENTER/DANIEL RUTTER



Sign of things to come? An immense sunspot that erupted in January

Sunspots reach unexpected peak

The current solar cycle is far more active than predicted

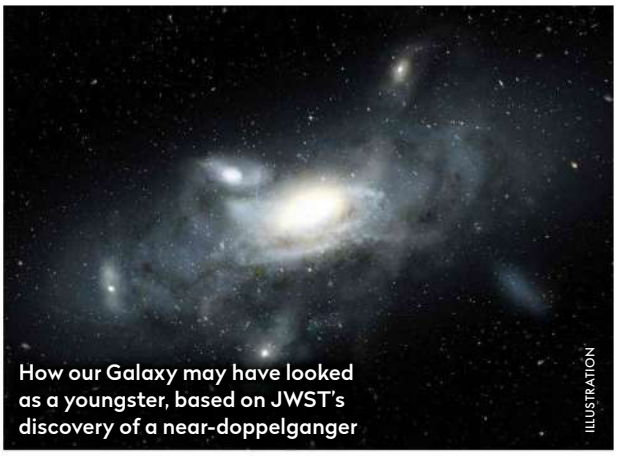
Things are heating up on the Sun as the number of sunspots hit a nine-year high in January 2023, with a total recorded number of 144. Solar activity is currently building and expected to peak in late 2024 or 2025, as part of the current solar cycle, the Sun's 11-year pattern of rising and falling solar magnetic activity that sees sunspot numbers correspondingly increase and decline. The last time such a large number of sunspots was seen was in February 2014, the previous cycle's peak.

Activity has been steadily declining over the last few cycles, and this solar cycle, number 25, was forecast to be equally low. The unexpectedly high activity also corresponds to an increase in the number of solar flares and other space weather, which has already resulted in a rare sighting of aurora as far south as Cornwall on 26 February, and may mean even more spectacular displays could be on their way.

www.swpc.noaa.gov

A view into our Galaxy's past

A younger version of our own Milky Way, recently discovered by the JWST, could give a window into our own Galaxy's youth, as it is far enough away that we are seeing it as it was nine billion years ago, when the Universe was only 4 billion years old.



How our Galaxy may have looked as a youngster, based on JWST's discovery of a near-doppelganger

ILLUSTRATION

The galaxy has been dubbed the Sparkler, due to the large number of globular clusters and satellite galaxies surrounding it. Our own Milky Way has 200 such clusters. The Sparkler as we see it is only 3 per cent the mass of our Galaxy today, but is expected to grow over time by merging with other galaxies. It is currently in the process of swallowing a dwarf galaxy.

"We appear to be witnessing, first hand, the assembly of this galaxy as it builds up its mass – in the form of a dwarf galaxy and several globular clusters," says Duncan Forbes from Swinburne University of Technology in Australia, who led the study. The distant galaxy is visible as its light has been magnified by gravitational lensing. The team will now attempt to take a deeper image of the Sparkler, hoping to find more clusters and satellites around the galaxy.

"We are excited by this unique opportunity to study both the formation of globular clusters and an infant Milky Way, at a time when the Universe was only a third of its present age."

www.swinburne.edu.au

NEWS IN BRIEF

Earth 2.0?

An Earth-mass planet around red dwarf Wolf 1069 could be a new hot spot in the hunt for extraterrestrial life. The planet takes 15.6 days to orbit its star, meaning that if the planet has formed an atmosphere the surface temperature would be a habitable 13°C, temperate enough for liquid water to pool on the surface.

Jupiter rules again

Twelve additional moons have been discovered around Jupiter, bringing its tally to 92. The moons are only 1–3km in size, but their discovery puts Jupiter back on top of the moon leader board after it was usurped in 2019 when a similar find brought Saturn's total to 83. Turn to **page 28** to read more about JUICE's exploration of Jupiter's largest moons.

Damp squib supernova

Binary star system CPD-29 2176 has an unusually circular orbit, new observations reveal. This could indicate that when one of the stars went supernova it did so with a fizzle rather than a bang, having had much of its material stolen by its smaller companion. If so, the system could be extremely rare, one of just 10 in the Galaxy.

NEWS IN BRIEF

Lone star

The mass of a lone white dwarf has been measured for the first time without the help of a companion star by the Hubble Space Telescope. The white dwarf is a microlens, meaning its gravity bends the light from a background star. Using this bending to weigh LAWD 37, astronomers found it to be 0.56 the mass of our Sun.

Sky at Night presenter made chancellor

Maggie Aderin-Pocock, co-presenter of *The Sky at Night*, became University of Leicester's chancellor on 1 March. Aderin-Pocock has a lifelong passion for education having grown up with undiagnosed dyslexia, and has gone on to demystify science for thousands of children over her career.

Twinkling black holes

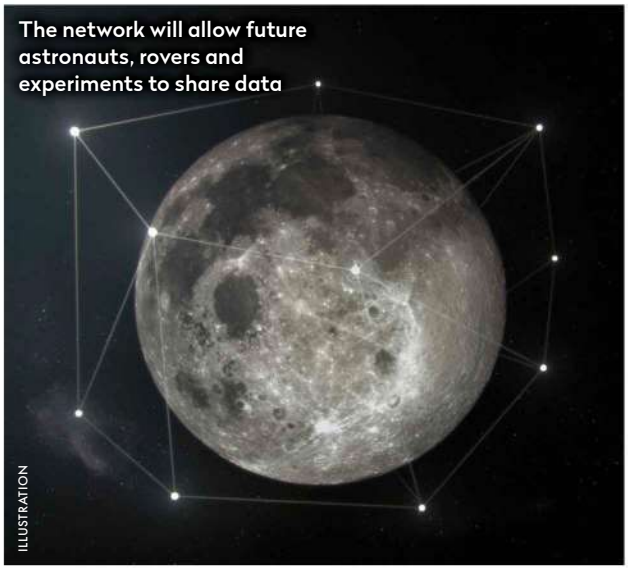
The glowing disc of gas surrounding black holes appears to 'twinkle', fluctuating in brightness from day to day. A new study of 5,000 such discs suggests that turbulence and instabilities in the gravitational and magnetic fields could be the reason behind this flickering appearance.

NASA/ESA/P. MCGILL (UNIV. OF CALIFORNIA/SANTA CRUZ AND UNIVERSITY OF CAMBRIDGE)/K. SAHU (STSCI)/J. DEPASQUALE (STSCI), ESA, NASA/ESA/CSA/I. LABBE (SWINBURNE UNIVERSITY OF TECHNOLOGY)/IMAGE PROCESSING: G. BRAMMER (NIELS BOHR INSTITUTE'S COSMIC DAWN CENTER AT THE UNIVERSITY OF COPENHAGEN)

BULLETIN

UK funding for new lunar network

The system will provide a single service for future Moon missions



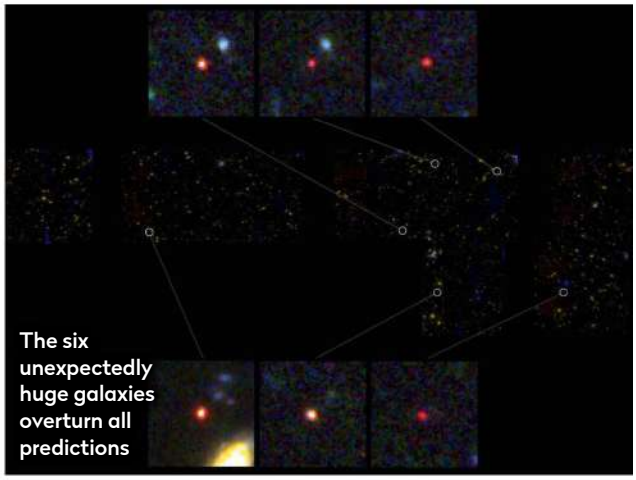
The network will allow future astronauts, rovers and experiments to share data

ILLUSTRATION

The UK has set its sights on the Moon, as the UK Space Agency has allocated over £50 million to develop lunar communications and navigations services. The funds are part of the European Space Agency's Moonlight programme, which aims to launch a constellation of satellites into lunar orbit capable of providing high-speed data transfer with Earth in 2028.

"This is an incredibly exciting time for space exploration, with the successful Artemis I mission paving the way for humanity's return to the Moon in the coming years," says UK Space Agency chief executive Paul Bate. "These endeavours are more international and more commercial than ever before – and by playing a leading role in the ESA Moonlight programme, we are opening up significant opportunities for UK companies to build on their extensive expertise in satellite technology and benefit from the new lunar economy." **space.blog.gov.uk**

JWST breaks theories of the early Universe

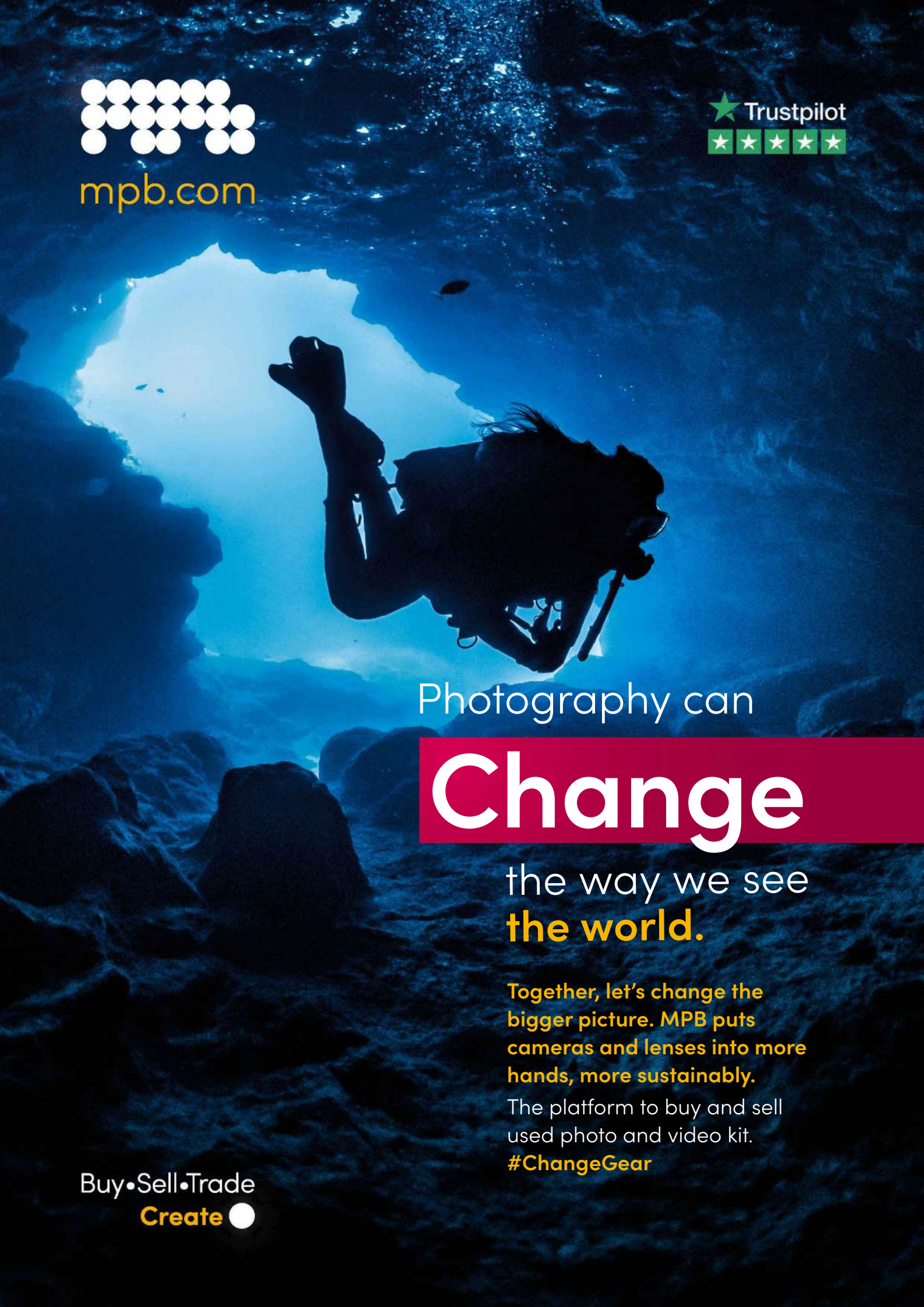


The six unexpectedly huge galaxies overturn all predictions

A set of 'Universe-breaking' galaxies could upend our ideas about how galaxies are born. The JWST is able to observe galaxies that are so distant that we're seeing them as they were just 500–700 million years after the Big Bang, giving a window into the epoch when galaxies were just beginning to form. These were all expected to be small, infant galaxies just beginning to grow, so astronomers were shocked to find six appear to have comparable masses to the Milky Way.

"This is our first glimpse back this far, so it's important that we keep an open mind about what we are seeing," says Joel Leja from Penn State University, who took part in the study. The team are now seeking follow-up observations to confirm if the galaxies really are as large as they seem.

"The amount of mass we discovered means that the known mass in stars at this period of our Universe is up to 100 times greater than we had previously thought. Even if we cut the sample in half, this is still an astounding change," says Leja. "The revelation that massive galaxy formation began extremely early in the history of the Universe upends what many of us had thought was settled science." **www.psu.edu**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Our experts examine the hottest new research

CUTTING EDGE

Our magnetic field can fight off particles blasted out from supernovae – but only if they're not too close

ILLUSTRATION

Saved from the supernova

Magnetic fields throughout the Galaxy could help deflect deadly radiation

Supernovae are one of the Universe's most cataclysmic events. When massive stars run out of nuclear fuel in their core, they can no longer hold themselves up against the immense crush of their own gravity and so suddenly collapse. This creates enormous shockwaves through the star and the outer layers explode violently outwards. The expanding shell of material sweeps through interstellar space and can trigger the formation of new stars. But some of these particles end up with a huge amount of energy and are shot across the galaxy as cosmic rays.

Earth is being constantly bombarded by a background flux of such galactic cosmic rays and they are one of the major hazards to astronauts venturing beyond the shielding effects of the planet's atmosphere and magnetic field. But if a supernova were to detonate particularly close to Earth, the point-blank blast of cosmic radiation could have serious consequences on a global scale. Computer simulations have shown that the pulse of energetic particles would drive a lot of chemistry in the atmosphere, creating compounds like nitrogen dioxide that cause acid rain and chemically attack the ozone layer (and so lead to greater levels of ultraviolet radiation from the Sun reaching Earth's surface). Some of the energetic particles created during these interactions – such as muons – also make it to the surface and so can pose a direct radiation hazard to life.

But there's been an important detail missing from previous studies on the terrestrial effects of cosmic rays from nearby supernovae. Due to the fact that they are charged, cosmic ray particles are deflected by magnetic fields; an effect that is more pronounced for the lower-energy radiation particles. This means that as the pulse of particles blasting out from a supernova travels to Earth, the lower-energy particles are scattered more by the magnetic fields threading through interstellar space and are effectively suppressed. Now, Brian Thomas and Alexander Yelland, at Washburn University in Kansas and MIT respectively, have run computer simulations that include this filtering effect. They found, as they had expected, that it reduces the impact of the cosmic ray surge on Earth.

The filtering effect is much more significant for more distant supernovae. At, say, 320 lightyears from Earth, the event probably wouldn't have any noticeable terrestrial effects. But for a supernova around 160 lightyears away, the enhanced stream of cosmic rays hitting Earth is still 10 times higher than background levels and lasts for centuries. For an especially close supernova, at 65 lightyears, Thomas and Yelland calculate that the flood of cosmic rays would surge to around 200 times higher than normal. This would have dire consequences for the planet, with at least 30 per cent of the ozone layer destroyed around the planet, and as much as 87 per cent in polar regions.

"For an especially close supernova, the flood of cosmic rays would surge to around 200 times higher than normal"

Thomas and Yelland conclude that while previous studies have significantly overestimated the radiation dose caused by a supernova 160 lightyears away, close-by supernovae would still have devastating consequences. Their results support the speculation that perhaps nearby supernovae are responsible for at least one of the mass extinctions of complex animal life on Earth over the past 500 million years. Fortunately, there are only two nearby stars which could go supernova within the next million years or so, Antares and Betelgeuse, both of which are over 500 lightyears away.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Terrestrial Effects of Nearby Supernovae: Updated Modeling* by Brian C Thomas and Alexander M Yelland
Read it online at: arxiv.org/abs/2301.05757

VIT_MAR/ISTOCK/GETTY IMAGES, CLAUDIOVENTRELLA/ISTOCK/GETTY IMAGES

Dark matter could be made of black holes

Are tiny black holes the gravitational glue holding galaxies together?

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

It's been obvious for a while now that our best theories of cosmology have a problem. Though we can build computer simulations that do a good job of reproducing the cosmos we see around us, they rely on the presence of dark matter. This mysterious dark matter, which outweighs normal, visible matter by a factor of six to one, is needed to provide the gravitational heft to form the structure of galaxies and galaxy clusters but must not interact with light.

We need something that is massive, and which is dark. It's only natural to think that black holes might be part of the answer. We know from surveys looking for the effect of passing black holes on background stars that there are not anywhere near enough large black holes in the Universe to make much of a dent in what's needed. But could smaller ones exist?

Current physics allows for the possibility that tiny black holes, each weighing about the same as a small asteroid – something like a billion, billion kilograms – may form right at the beginning of the Universe. The trouble is that we believe black holes evaporate through a weird quantum mechanical process known as Hawking radiation, after Stephen Hawking who discovered it. For massive specimens, like the 3-million-solar-mass behemoth at the centre of the Milky Way, the slow release of this energy is too small to have any meaningful effects; but for tiny primordial black holes it will be lethal. They should evaporate away long before the present day, making them useless as candidates for dark matter.

This month's paper suggests a solution. Black holes have a mass, but they also have two other properties which affect their behaviour. They spin – and results from the LIGO gravitational wave observatory suggest that larger black holes, at least, are spinning – and they might have charge. (In fact, the famous and stupidly-named 'no-hair theorem' suggests that these are the only three properties someone on the outside of a black hole could measure – mass, charge and spin.) Spinning, charged black holes, it turns out, might survive for much longer, and perhaps for long enough to be a viable source of dark matter.

What's more, it turns out that such black holes could be smaller, perhaps the mass of an aircraft carrier, and still be stable. Such small black holes might fill the cosmos, providing the gravitational glue that shapes everything we see on the largest scales.

Of course, there's no actual evidence that such small black holes do form in the early Universe or exist today. With little prospect of new observations sensitive to such elusive beasts, you might think that this work does little more than re-label the problem – 'dark matter' replaced with mysterious, hypothetical, weird black holes. Still, it does make a case for more theoretical work, and it seems possible that whatever process forms these things might also produce more massive examples, which would be detectable. If we want to understand the Universe's mysteries, we're going to have to look.

> ***"Such black holes could be smaller, perhaps the mass of an aircraft carrier, and still be stable"***

Spinning, charged, mini black holes could be one part of the mystery that is dark matter

ILLUSTRATION

Chris Lintott was reading... *Quasi-extremal Primordial Black Holes are a Viable Dark Matter Candidate* by Jose A de Freitas Pacheco et al.
Read it online at: arxiv.org/abs/2301.13215

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

ILLUSTRATION

As this month's show looks at exoplanets, **Emma Johanna Puranen** reflects on how alien worlds bring science and science fiction together

▲ An artist's interpretation of a world with three moons and two suns. Emma examines where science ends and fiction begins in works portraying fictional planets

In just a generation, humanity has gone from knowing of a handful of planets – those in our Solar System – to confirming the existence of over 5,000. While many of these newly discovered exoplanets remain invisible, detected not from their own light but through their effects on their host star, that hasn't stopped scientists and artists alike from understanding and imagining them not as mere data points but as fully-fledged worlds.

My own love story with exoplanets began in a car park atop Kitt Peak, a mountain in the Arizona desert that's home to around two dozen telescopes. It was July 2013 and I was a teenager at Astronomy Camp, using the Kitt Peak Visitor Center's Roll Off Roof Observatory to observe a transit of TrES-3b, a puffy gas giant planet with a blisteringly short year of just 31 hours. As the telescope imaged the star, I went outside and laid down on the asphalt, which still warmly radiated the heat from the day. I'd never been to a dark-sky site before. Seeing the stars in all their glory, I felt dizzy, like I had to clutch at the ground around me or else I'd fall up into the heavens. As I lay, I thought of 'my' hot Jupiter out there, passing between us and its sun. I wondered how many other stars in my view hosted invisible planets. I wondered what they would look like from orbit, or from their surfaces, if they had them. I wrote stories in my head about these new types of worlds.

A meeting of minds

Nearly 10 years (and 4,000 confirmed exoplanets!) later, I am a PhD student at the University of St Andrews Centre for Exoplanet Science. My research is interdisciplinary; I study portrayals of exoplanets in science fiction. In particular, I use data science methodology to look at how scientific concepts like exoplanets flow from scientists to the public through the intermediary of science fiction. Building up an entire world, from its physical environment to its biology (if it has any), is a labour-intensive process, and authors often do a lot of research. I consider questions like: where do writers get their scientific information from? How do they make decisions on

DOTTEDHIPPO/ISTOCK/GETTY IMAGES, NASA/JPL, NASA/ESA

Emma Johanna Puranen is a PhD researcher with the St Andrews Centre for Exoplanet Science

where to remain scientifically accurate and where to make things up? What might science fiction look like if the writer had a dedicated science consultant?

And so I conceived a project. I paired scientists in fields from astronomy to earth sciences with writers from the university's School of English. Each pair created a science fiction story based on the scientist's research. Through questionnaires filled out by all the participants, I learned about their thought process as they constructed their worlds. Participants expressed how they wanted their stories to inspire readers to go and learn about strange and exciting new exoplanet findings. They also wanted to convey the deep sense of reaching into the unknown that is palpable for anyone involved in exoplanet science. The resulting anthology, *Around Distant Suns*, features a diverse array of worlds, from a planet covered in sentient mist to one where it rains graphite, and another that is the rocky core of a gas giant that has had its atmosphere stripped.

Most importantly, the collection highlights the ways we all yearn to engage with exoplanets. These worlds represent the big questions that all of us – scientists, artists and everyone else – are asking: what is out there, past the edge of the known? With every new planet, we are closer to knowing.

Looking back: The Sky at Night

11 April 1981

On the 11 April 1981 episode of *The Sky at Night*, Patrick Moore looked towards the moons of Saturn. The previous November, Voyager 1 had given humanity its first close-up look at these frozen worlds, and the show aired just as NASA had begun to publish maps created from its images.

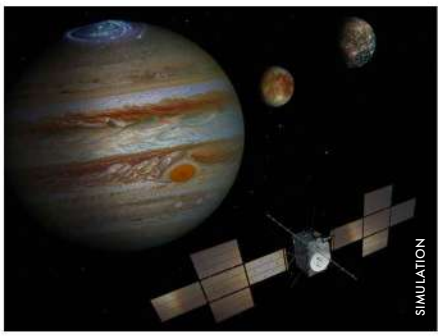
▲ **Voyager 1 image of Saturn's moon Mimas, November 1980**

Voyager 1 captured the surfaces of Tethys, Mimas, Rhea, Dione and Enceladus. As most of the moons were imaged from over 100,000km away, only major features were obvious, but they did reveal a large crater on Mimas (giving it a striking resemblance to the Death Star from *Star Wars*). Fortunately, Voyager 2 would be able to give them all a second look when it arrived in the system that August. Voyager 1 did pass much closer to one other moon – Saturn's largest, Titan – but its thick, haze-filled atmosphere blocked the view from its optical cameras. It found that the moon was 5,150km across, making it the second-largest in the Solar System (after Jupiter's Ganymede), and slightly bigger than the planet Mercury. It also found the surface pressure was 1.6 times that of Earth and contained organic chemicals like ethane and acetylene, but was a frigid 180°C. At that temperature, it could well be possible for liquid methane lakes and rivers to exist on the surface, but planetary scientists would have to wait until the Cassini–Huygens probe arrived in 1997. Using its radar, that craft was able to pierce the haze and finally map out Titan's river-carved surface.

Searching for Alien Life

The launch this April of the JUICE mission to Jupiter and its icy moons marks a new era in the search for habitable conditions beyond our planet. *The Sky at Night* meets scientists who are collecting samples from Mars, exploring the Jovian system and beyond to find out how we're looking for extraterrestrial life – and whether we'll know when we've found it.

BBC Four, **10 April,** 10pm (first repeat will be on BBC Four, **13 April**, 7pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information



▲ **Find out more about ESA's JUICE mission to explore Jupiter's icy moons on page 28**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: two Philip's titles

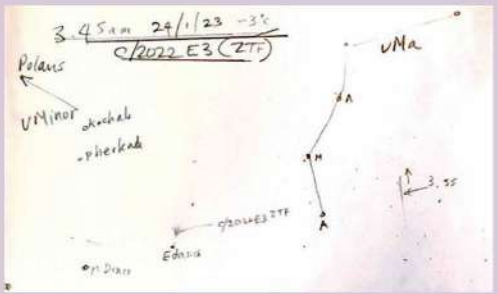
The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2023* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Drawn to comets

Comet C/2022 E3 ZTF has been a delight, watching it rise in the morning and evening sky. A comfy seat and some simple sketches gave a view of this memorable sight, clearly seen from town. There was hardly any difference in the views from my 6-inch achromat or 15x70 binoculars. The coma looked green and a wide tail was seen by averted vision and noting which area of the sky appeared misty.
Nicholas Cox, Swadlincote, Derbyshire

What a great drawing, Nicholas. Well done on staying out so late in a very chilly –3°C! **– *Ed.***

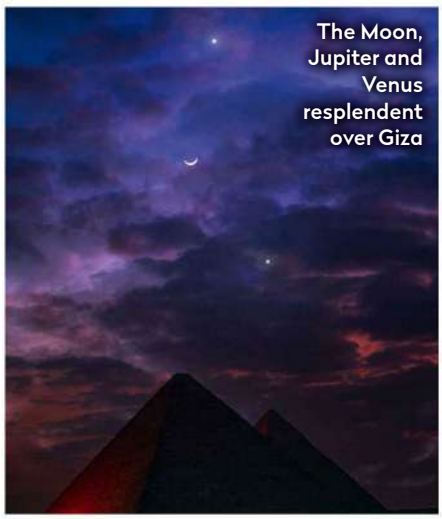


▲ **Nicholas braved the elements to sketch his view of the comet in the wee small hours**

◀ **His record of C/2022 E3 ZTF's journey into Ursa Minor, brightening all the while, in January**

Tweet

Andrew Morl
@AndrewMorl • 26 February
Aurora tonight now as we speak from @GrassholmeObser. Best display I have ever seen. Image from the back of the camera. More to come @BBCNEandCumbria @skyatnightmag



The Moon, Jupiter and Venus resplendent over Giza

Pyramid party

I would like to share this photo with you to publish in your honoured magazine: the crescent Moon, Jupiter and Venus above the Great Pyramid of Giza on 22 February. The gear it was taken with was a Sky-Watcher Star Adventurer tracking mount, modified Nikon Z6 mirrorless camera and Sigma 28–70mm lens, ISO 200 and a 1/30-second exposure at f/2.8.
Osama Fathi, Cairo

Dark dealings

I read this morning that astrophysicists are claiming that dark energy comes from black holes. One problem that occurs to me is that black holes are found at the centres of galaxies and dark energy is manifesting itself by expanding space between galaxies, so effectively pushing galaxies apart. Yet there is no suggestion that galaxies themselves are expanding; instead seemingly, at least in part, they

Geoff captured this terrific trio with his DSLR

are held together by dark matter. This new theory appears to require dark energy to be in two places at once.
Brian Jolliffe, via email

Fancy three

This is my effort (above) at capturing Jupiter, a crescent Moon and Venus on 22 February. The earthshine shows well, but the crescent is a little over-exposed. It was taken with a Canon EOS 6D DSLR camera and 24–105mm lens, ISO 1600 and a 1-second exposure at f/4.
Geoff Smith, Rafford, Inverness

Shuttle song

Following your article on the Columbia disaster (Explainer, February 2023), I thought that readers would be interested in a very poignant postscript to the event. Mission specialist Laurel Clark's ancestors emigrated from Scotland to the US in the 1880s and she was always very proud of her heritage. In the 1990s, she was stationed with the US Navy submarine squadron at the Holy Loch on the Firth of Clyde. During this time she heard and fell in love with the music of Scottish band Runrig. Fast-forward to 2003, and, along with other crew members, she was allowed to take a CD on board the Shuttle. She chose a Runrig album to use the track 'Running to the Light' as her wake-up and exercise music. This was the last music the crew heard.

Among the wreckage, the searchers found a CD player with the Runrig CD still inside. On hearing of the disaster, Runrig percussionist Calum Macdonald said: "Laurel was a very special Runrig fan. She'd been featured in one of our newsletters just before the ▶

ON FACEBOOK

As Comet C/2022 E3 ZTF left our skies, many of you got in touch to share your experiences.

Thomas Kempf I watched it with my family and it looked wonderful. In 50,000 years the world will be a complete other world; maybe those people will watch it from the outer planets or the Moon.

Neil Kondel I saw it only once last week when it was getting more faint through my binoculars. I was glad that I had a chance to see it.

Nicole Bedford It took a bit of research to find its exact location, but it was well worth it.

Aubrey Stout I'm so glad my 10-year-old nephew was able to see it. He is a science and history kid and seeing this made him so excited.

Ralph Hengst I said goodbye on Monday 13 February, when it nearly passed NGC 1647, the wonderful small open cluster. The comet was still nice through my telescope.

Corrina Turner Very lucky to see it using my binoculars. Once in a lifetime opportunity.

Jimmy Murley My grandsons and I will never forget seeing it.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

In the sub-zero weather this winter, my 8-inch Go-To Schmidt-Cassegrain telescope won't move vertically to align on a star, though I can power it up and move it horizontally. Can you help?

GARY WALKER

Even your handset can fail in very cold weather

As the temperature decreases, the viscosity of the lubrication in the gears and bearings of many mounts will start to increase, causing a greater load on the motor drive and even initiating a motor stall if it is cold enough. This could affect either or both axes. If you are using batteries to power your mount, the electrochemical reaction that produces the electric current will slow down with decreasing temperature, reducing the power of the battery, sometimes to below the minimum required for full operation of the mount.

Very low temperatures can cause the display on your hand controller to fade until it is unreadable. If you are very unfortunate and have a faulty solder joint or crack in one of the tracks on the mount's printed circuit board (PCB), the contraction of the PCB and its components with decreased temperature can cause a disconnection in the circuit.

Keeping the mount warm using a chemical hand-warmer and placing external batteries in an insulated box with a hand warmer may well resolve the issue.

Steve's top tip

What is backlash?

Astronomical mounts and focusers often rely on the action of gears to make them move. These have teeth that mesh with the teeth of another gear, the worm thread of a worm gear or the rack of a rack and pinion drive. Ideally, this meshing of the gears would be perfect with no gaps, but manufacturing tolerances and the need for lubrication mean that there is usually a small gap between the mating surfaces. This gap results in a small amount of play in the gears that is most obvious when changing the direction of travel, resulting in a slight delay in the movement. This is known as backlash.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

BBC Sky at Night Magazine is published by Our Media Ltd (an Immediate Group Company) under licence from BBC Studios, which helps fund new BBC programmes.

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Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 03330 162119 (UK); overseas +44 (0)1604 973727

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Audit Bureau of Circulations
21,760 (combined, Jan–Dec 2022)

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ISSN 1745-9869

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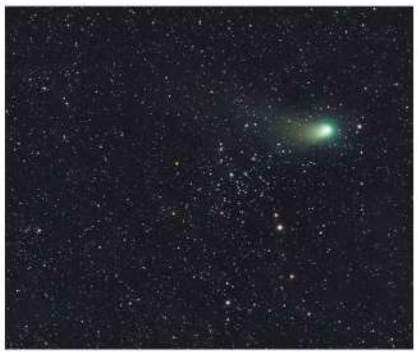
Instagram

bemostar • 19 February

Comet C/2022 E3 ZTF in the constellation Taurus. The comet moved to the constellation Taurus and was close to NGC 1647 on 13 Feb and to the star Aldebaran on 14 Feb. Telescope: Askar ACL200 f/4 APO lens. Camera: ZWO ASI533MC Pro. Subs of 90 seconds. UV/IR cut filter @bbcskyatnightmag @zwoasi



▶ Columbia mission. She'd planned to photograph herself in space for the next issue. When we got news of the accident, we couldn't believe it."

Some time later, Laurel's husband and son met with the band in Glasgow and presented them with the CD that had been recovered from the wreckage. Runrig subsequently dedicated the final track 'Somewhere' on their final album *The Story* to Laurel, whose voice can be heard as the track fades out.

Bill Smith, Ayr

Fighting talk

Douglas Vakoch's appearance on TV and subsequently in *Sky at Night Magazine* in February (Inside *The Sky at Night*) sent a chill up my spine. I would love to see enlightened aliens gently greeting us and teaching us to treat each other more kindly, like in some Hollywood depictions, but we simply have no idea what any alien species may be like in reality. By sending messages designed to be received by unknown intelligences, isn't Douglas risking the safety of humanity by potentially attracting the attention of more advanced and equally violent species as our own? I think sending messages out to unknown recipients is a risk to our safety, and I hope Douglas you are listening more than they are, for all our sakes.

Chris Barker, Dorset

CORRECTIONS

In 'Chelyabinsk: 10 years on' (February 2023 issue, page 38), we incorrectly stated that the asteroid's mass was 130,000 tonnes; it was 13,000 tonnes.

SOCIETY IN FOCUS

Preston and District Astronomical Society (PADAS) is a friendly group of amateur astronomers, welcoming to everyone from complete beginners to seasoned observers and astro imagers. PADAS has a rich history dating back to the Preston Scientific Society, formed in 1876, and its active astronomical section.

We meet at 7:30pm on the second Thursday of the month at Deepdale Labour Club for our guest speaker nights. On the fourth Thursday of the month we hold our members' night at the historic Jeremiah Horrocks Observatory. We have a good collection of telescopes for observing: a 16-inch truss tube Dobsonian, a 12-inch Meade SCT, plus medium to small telescopes and a solar telescope.

The society is very active with public outreach. On the third Thursday of each month, from October to March, we host public observing nights at the observatory, which houses the historic 8-inch Cooke refractor. The observatory was designed by George Gibbs and opened to coincide with the 29 June 1927 total eclipse. The dome is currently unserviceable, but will hopefully be repaired in the near future.

▲ One of the observing nights for the public at the Jeremiah Horrocks Observatory

We have a good relationship with the Jeremiah Horrocks Institute at the University of Central Lancashire, hosting joint events and assisting with their public observing nights at Alston Observatory throughout October to March.

▶ www.padas.org.uk

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

JAMIE CARTER X 4

The Future of Geography

Sheffield Central Library, Sheffield, 24 April, 6:30pm

Author and journalist Tim Marshall gives a talk on the politics of space and how humans are taking their power struggles with them as they explore the Solar System. Free.

www.eventbrite.co.uk/o/libraries-sheffield-9795467632

Astronomy history conference

Lyttelton Lecture Theatre, Birmingham, 1 April

The Society for the History of Astronomy hosts a day of fascinating talks, headlined by Carolyn Kennett on the 1820s Dolcoath Mine experiments to calculate Earth's gravity. £20 for non-members.

societyforthehistoryofastronomy.com/meetings

Astronaut Academy

Observatory Science Centre, Herstmonceux, East Sussex, 4 April

Half-day workshops for children aged 6–8 and 9–11, discovering what it takes to become an astronaut, doing robot arm experiments and learning about life in microgravity. £14.95 per child.

www.the-observatory.org/events/astronaut-academy

The Hidden Universe

14 April, 8pm

Dr Jeni Millard presents an online talk on the bits of the Universe we cannot see, the many different wavelengths of light, and how they can uncover the secrets of the cosmos. £3 for non-members.

www.midkentastro.org.uk/events

PICK OF THE MONTH

▲ AstroCamp's friendly meet-up takes place under the dark skies of the Brecon Beacons

AstroCamp

Cwmdu, Powys, Wales, 22–25 April

A star party weekend in the Brecon Beacons Dark Sky Reserve with talks, workshops, a pub quiz, a limerick competition (with prizes) and plenty of stargazing opportunities, weather permitting, including tours of the night sky with experienced astronomers. With its relaxed atmosphere, the camp offers a social area where anyone can get a look through a telescope, and you don't need to bring your own equipment with you. Previous years have provided views of planets, nebulae, comets and galaxies, while the local cafe and pub take care of non-astronomy related needs. From £25.

astrocamp.awesomeastronomy.com

Observing night

University of Glasgow Observatory, Acre Road, Glasgow, 18 April, 6:30pm

On a night with just a 6% crescent Moon, Glasgow University Astronomical Society members will be observing the skies above the city. Free. All are welcome.

www.facebook.com/guastrosoc

Public stargazing session

Binham Village Hall, Fakenham, 20 April, 7:30pm

This North Norfolk Astronomy Society event includes a presentation on the planet Jupiter and telescope viewing if clear. £4 for non-members.

garyvheard.org/joomla30

Stargazing Safari

Tudor Farmhouse Hotel, Clearwell, Gloucestershire, 22 April, 8pm

From a hill in the Forest of Dean, storyteller Jim Bell will point out stars, planets and constellations. There's a portable planetarium in case it's cloudy. Adults £40, £20 for children.

tudorfarmhousehotel.co.uk/stargazing-safari

The Royal Institution
Science Lives Here

Out of this world science talks

The Ri is the place for science enthusiasts, the curious, and anyone after a night out with a difference.

Our latest season of fascinating in-person and online science talks is live now. Explore what's on and join the conversation.

rigb.org/whats-on

@Ri_Science @RoyalInstitution Image credit: Daniel Olah via Unsplash

At the limits of astrophysics
Thursday 23 March – astrophysicist Katy Clough

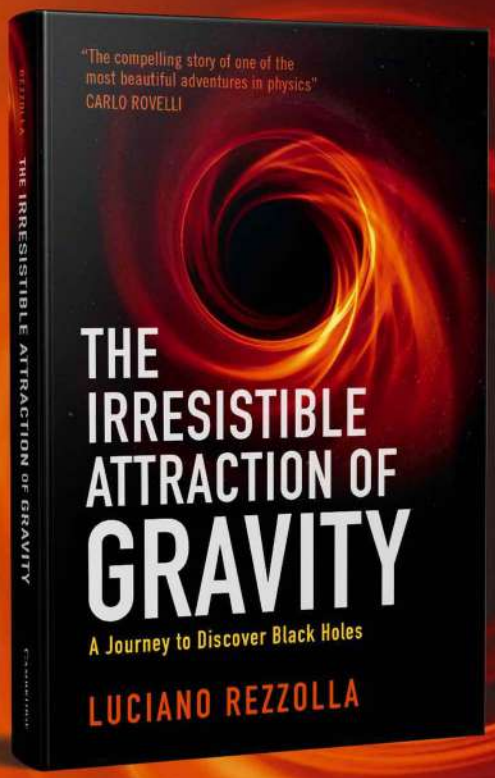
First starlight: The quest for cosmic dawn
Monday 27 March – astrophysicist Richard Ellis

On the origin of time
Tuesday 28 March – cosmologist Thomas Hertog

A traveller's guide to the stars
Thursday 6 April – physicist Les Johnson

Supernova science: Destruction in the stars
Tuesday 11 April – astrophysicist Thomas Haworth

The dark energy of Einstein's aftermath
Tuesday 25 April – cosmologist Chris Clarkson


"The compelling story of one of the most beautiful adventures in physics"
CARLO ROVELLI
THE IRRESISTIBLE ATTRACTION OF GRAVITY
A Journey to Discover Black Holes
LUCIANO REZZOLLA

What is gravity and how does it work? This engaging book delves into the bizarre and often counter-intuitive world of gravitational physics. Distinguished astrophysicist Professor Luciano Rezzolla leads this virtual journey into Einstein's world of gravity, with each milestone presenting ever more fascinating aspects of gravitation.

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FIELD OF VIEW

The very, very early Space Race

No engine? No problem! **Jonathan Powell** on the daring early days of rocket science

Fly my pretty! The ancient Greek space programme pioneered the use of steam pigeons

Jonathan Powell is a freelance writer and broadcaster. A former correspondent at BBC Radio Wales, he is currently astronomy columnist at the *South Wales Argus*

Humankind's passion for exploration – to forge that raging river or climb that lofty snow-capped mountain – has been at the heart of many an expedition.

Over time, those rivers were forged, those mountains climbed and new lands discovered. However, to many explorers the thought of venturing beyond Earth to see exactly what those points of light were in the night sky seemed a mere dream. But for a tenacious few, it was yet another challenge to engage with.

Long before Yuri Gagarin's epic voyage in 1961 on board Vostok 1, powered by a Vostok-K rocket, history recalls others who dared to dream. One such soul ready to conquer the heavens was 16th-century Chinese would-be astronaut Wan Hu, a public official with stars in his eyes.

Wan Hu, or Wan Tu (depending on which source you consult), was determined to breach Earth's protective atmospheric shell. The cockpit of his 'craft' was a specially designed chair; his Saturn V engines were 47 rockets strategically distributed around him. The craft also boasted a guidance system – an array of kites, for wind assistance and stability.

Once representatives from Health and Safety had quickly thumbed through manuals on all the potential issues that might present themselves, Wan Hu was ready to be blasted into space. Sporting suitably lavish attire to mark the occasion, the rocket fuses were duly lit by the mission control ground crew.

As a precursor to the present-day phrase "lighting the blue touch-paper and retreating", one can only imagine the hasty withdrawal from the launch scene that followed. While it would have been fabulous to see Wan Hu blast off skyward just like Artemis I, the actual outcome was ultimately unfavourable. The craft did move some distance, but an explosion and clouds of smoke followed, and his dream apparently ended there.

Rockets could well date further back than Wan Hu's assembled collection, as far back as 400 BC when Archytas, a Greek philosopher and mathematician, showed off his own pseudo-rocket, which took the form of a wooden pigeon and was propelled by escaping steam.

Centuries later, in 1232, in one of the first uses of rockets for military purposes, the Chinese used arrows attached to gunpowder-filled tubes, launching them to engage the Mongols in battle. During the late 1800s and early 1900s, Fritz von Opel, a German automotive industrialist, not only beefed up the car to achieve great speeds with rocket propulsion, but applied the same mechanics to powering aircraft. His rocket plane earnt him the name 'Rocket Fritz'.

However, in 1926 Professor Robert H Goddard, US engineer and physicist, revolutionised the field of rocketry. Goddard is hailed as the father of modern rocketry for his visionary approach, as he was the first to successfully launch a liquid-fuelled rocket.

There are those who design and build rockets, and those prepared to sit surrounded by them like Wan Hu, – or indeed on top of 500,000 gallons of fuel like the Apollo crews. These are the true pioneers who made space travel possible, with a combination of both ingenuity and bravery.

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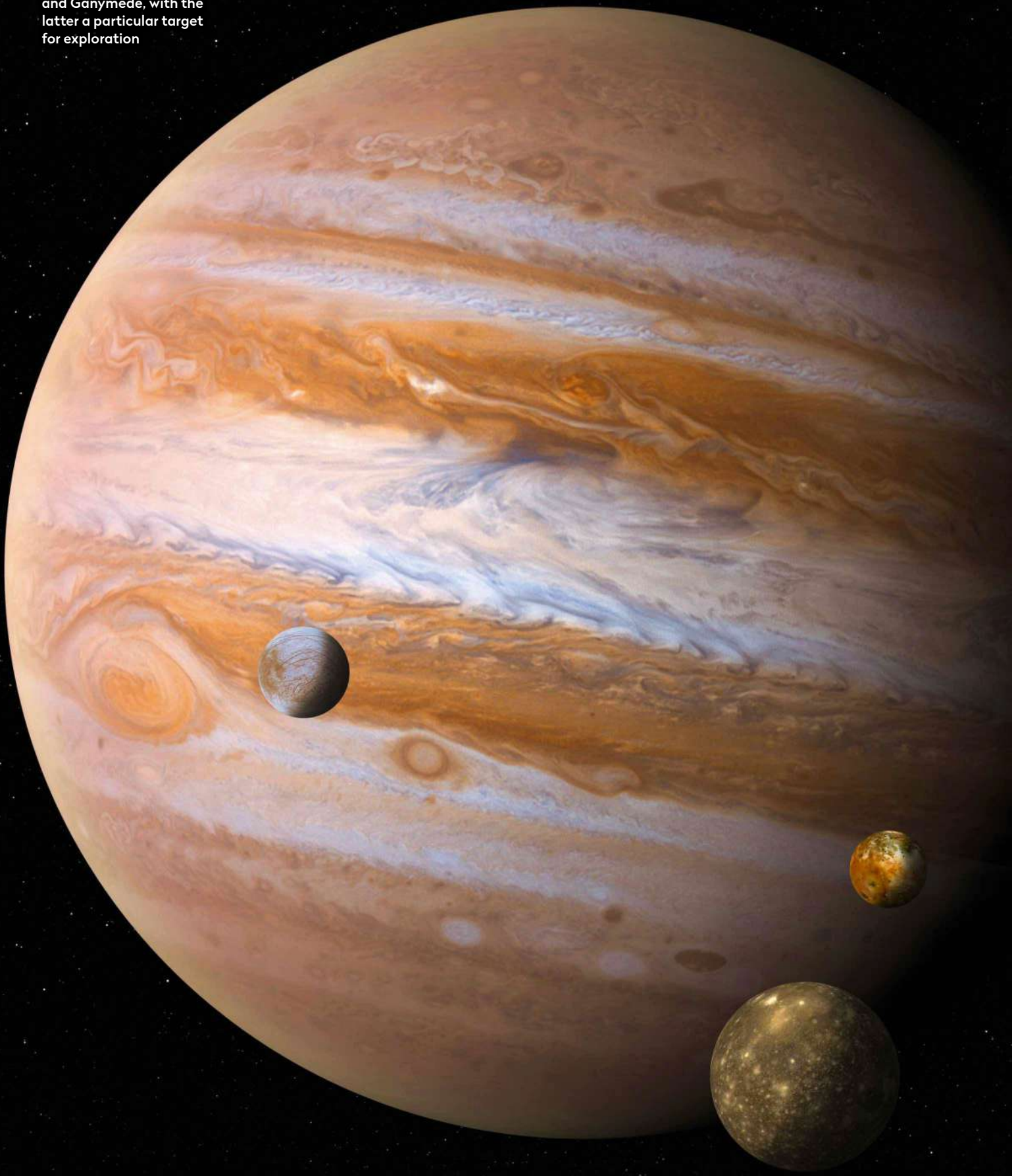

JUICE will visit all of the Galilean moons, (left to right) Europa, Callisto, Io and Ganymede, with the latter a particular target for exploration

JUICE TAKES FLIGHT

Set to launch this month, the European-led JUICE spacecraft will explore the frozen worlds orbiting the gas giant Jupiter. **Will Gater** reports on the exciting flagship mission

This month ESA's JUICE mission is due to thunder into the skies, carried aloft by a mighty Ariane 5 rocket. As the venerable European launcher soars above the palm trees around the spaceport in French Guiana, JUICE – the Jupiter Icy Moons Explorer – will be some eight years from its final destination: Jupiter, the largest planet in the Solar System, and its enigmatic collection of satellites.

Through a series of fly-bys of both Earth and Venus, the mission will slingshot its way across the Solar System, crossing the gulf between our world and the Jovian system to arrive there in the summer of 2031. It's a voyage only a small number of spacecraft have ever achieved. Once at Jupiter, JUICE will swoop past the three icy moons Callisto, Ganymede and Europa multiple times, before settling into orbit around Ganymede in 2034. For those working ▶

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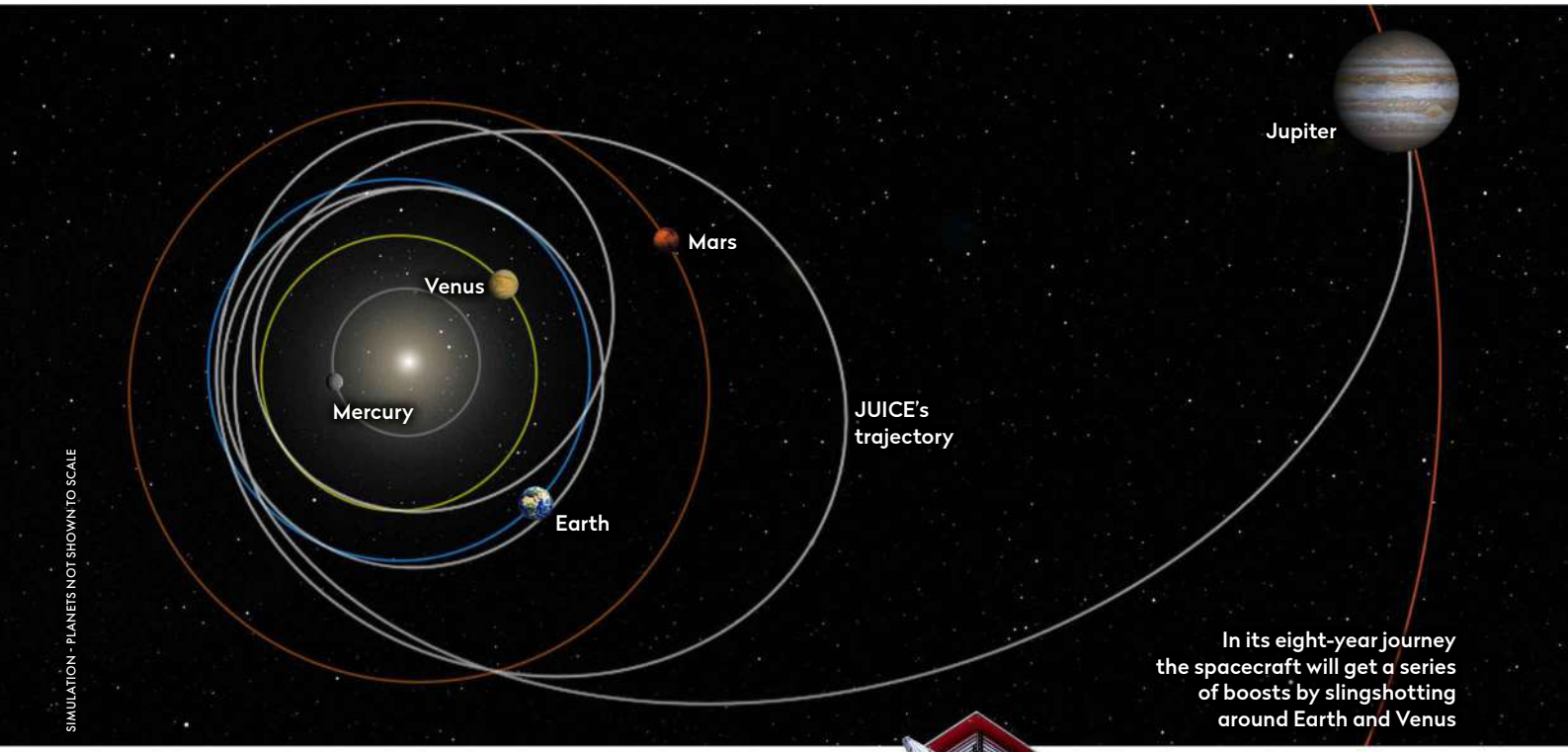


In its eight-year journey the spacecraft will get a series of boosts by slingshotting around Earth and Venus

▶ on JUICE, it will be a chance to dive deep into the secrets of worlds whose mystery has only grown the more humanity has learnt about them.

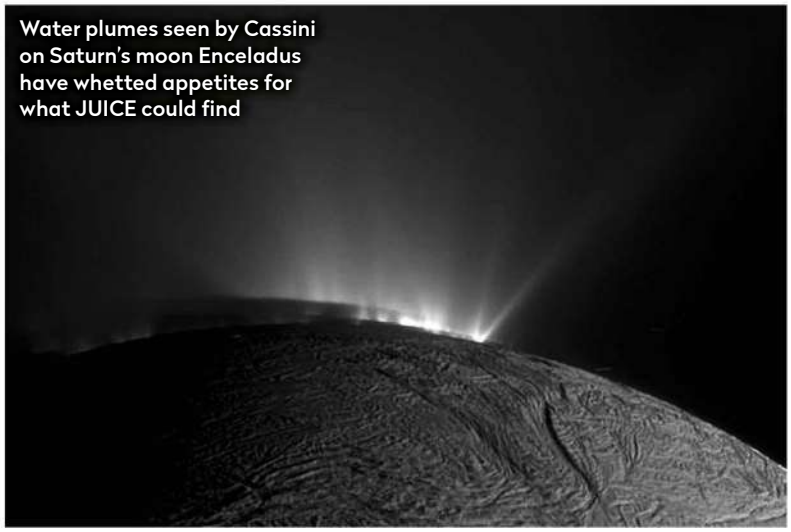
Professor Michele Dougherty, a planetary scientist based at Imperial College London, is one of many researchers eager to explore the Jovian system. Her involvement in JUICE has been a long one, stretching back some 15 years to the early planning days, when it was going to be a joint US and European project. Now Dougherty is the lead scientist on the magnetometer that JUICE will carry with it to Jupiter. This instrument, built here in the UK, will examine the magnetic fields of the moons Callisto, Ganymede and Europa in unprecedented detail. And indeed it is those fields, or rather what they hint at, that are one of the biggest draws to exploring these icy worlds.

Four not of a kind

The magnetic fields were previously investigated by NASA's Galileo spacecraft, which carried out a ground-breaking study of the Jovian system in the late 1990s and early 2000s. Through fly-bys of the Galilean moons – Io, Europa, Ganymede and Callisto – the mission painted a remarkable portrait of the four largest moons of Jupiter, one that showed each satellite to be captivating in its own right. Galileo's pictures revealed the moons' surfaces in a level of detail never before seen: Io with its sulphurous yellow globe scarred by numerous volcanoes; Europa and its ice crust riven with immense fissures and fractures; and Ganymede and Callisto, the former larger than the planet Mercury, with their cratered, frozen forms.

Yet it was the magnetic field data from the last three that particularly intrigued scientists. This seemed to suggest that deep beneath the frozen exteriors of these moons were salty, liquid water

After long years in development, in February JUICE arrived at the spaceport in French Guiana



Water plumes seen by Cassini on Saturn's moon Enceladus have whetted appetites for what JUICE could find

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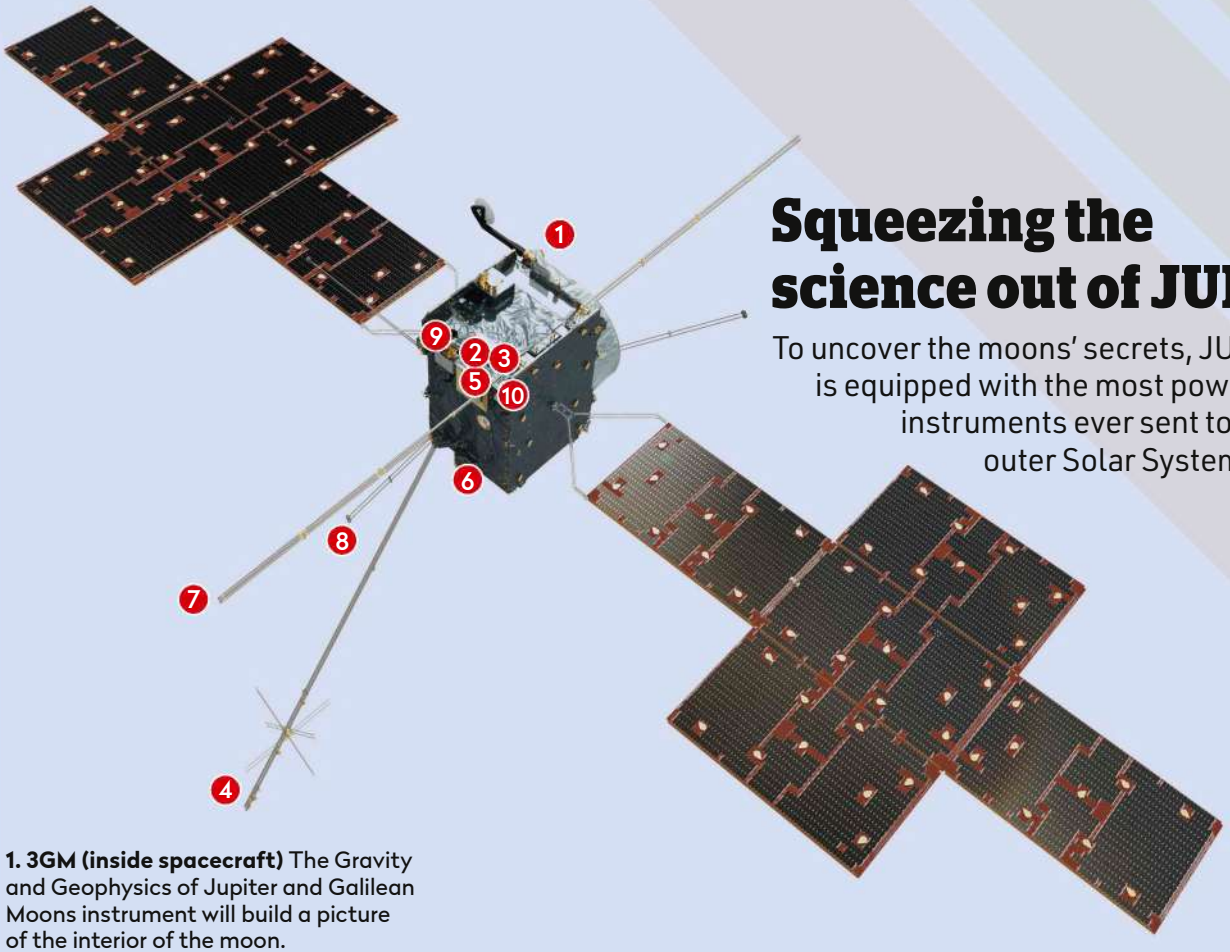


Squeezing the science out of JUICE

To uncover the moons' secrets, JUICE is equipped with the most powerful instruments ever sent to the outer Solar System

1. 3GM (inside spacecraft) The Gravity and Geophysics of Jupiter and Galilean Moons instrument will build a picture of the interior of the moon.

2. GALA The Ganymede Laser Altimeter will bounce a laser off the moon to create a detailed 3D model of its surface terrain.

3. JANUS The camera on board JUICE will take detailed images of the Jovian system. At Ganymede it should be able to pick out features just a few metres across.

4. J-MAG The UK-led magnetometer will measure the magnetic fields of both Jupiter and its moons, and which are key to understanding the nature of the internal oceans of Ganymede and Callisto.

5. MAJIS The Moons and Jupiter Imaging Spectrometer will examine the chemical fingerprints hidden within the light from its targets, revealing the composition of Callisto and Ganymede's surfaces.

6. PEP The Particle Environment Package will analyse the clouds of particles, plasma and gas that swirl around Jupiter, including the extremely tenuous outer atmospheres or 'exospheres' of Ganymede, Callisto and Europa.

7. RIME The Radar for Icy Moons Exploration instrument will probe the frozen crusts of Ganymede and Callisto to around nine kilometres below their surfaces.

8. RPWI Sensors on the Radio and Plasma Wave Investigation instrument will shed light on many processes, such as particles bombarding the surface and will even investigate any plumes.

9. SWI Jupiter and its churning atmosphere will be one of the key targets for the Sub-millimeter Wave Instrument, which can study the wind speeds in the gas giant's stratosphere.

10. UVS The UV Imaging Spectrograph will analyse the aurorae that dance around Jupiter's poles, as well as examining the exospheres of Ganymede and Callisto.

oceans. Given liquid water's link to habitable environments and life on Earth, the results were tantalising. What's more, the quantities may be substantial – some estimates suggest there could be more water within Ganymede than there is sloshing around on our own planet.

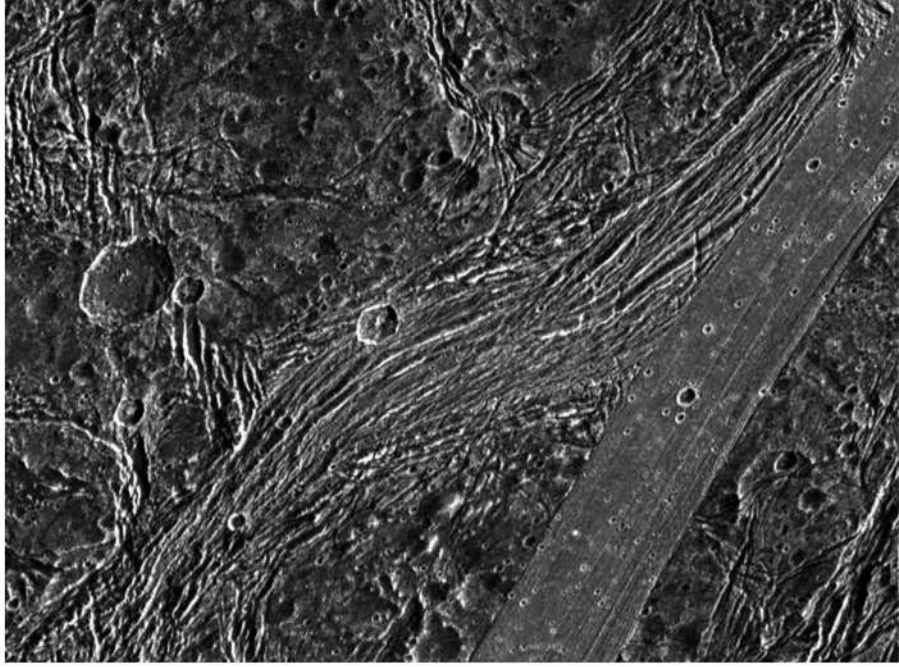
Fast-forward to the findings of the more recent Cassini mission – which explored Saturn and its moons, observing immense plumes of water vapour jetting from the moon Enceladus and evidence for a liquid water ocean within Titan – and it becomes clear why interest in these icy satellites has only accelerated. "All of those discoveries have now focused our minds," says Dougherty. "If we're searching for habitability, we don't need to focus on Mars only, we can look further out in our Solar System."

It's in this context that JUICE now finds itself bound for distant Jupiter, not just to explore an intriguing collection of worlds, but to gain a deeper understanding of potential environments for life in our planetary neighbourhood and, by extension, similar spots in other star systems.

Tooled up

When it arrives at Jupiter in 2031, JUICE will be fully equipped to scrutinise the moons it studies. As well as cameras, its onboard hardware includes a laser altimeter, an instrument for studying the gravity fields of its targets, spectrometers for establishing surface compositions, and the magnetometer that Dougherty and her colleagues have been working on.

It will initially spend several years performing fly-bys of Europa, Callisto and Ganymede, examining them up-close. While Europa will get its own dedicated visitor in the coming decade in the form of NASA's Europa Clipper mission, it's Ganymede that JUICE has set its sights on. The spacecraft will enter into orbit around the 5,260km-wide moon in ▶

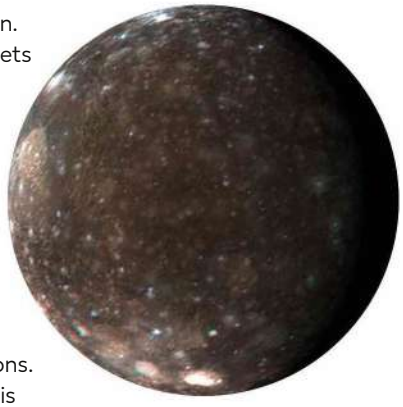


▶ Nine months will be dedicated to Ganymede, where JUICE will closely examine its magnetic field and aurorae, and map minerals on its surface

▶ December 2034 and spend around nine months circling the satellite gathering an extraordinarily rich data set. It will be in this phase that Dougherty and her colleagues working on JUICE's magnetometer will really get a chance to pin down the internal structure of the moon and the nature of the water lying beneath its icy crust.

The instrument will be looking for what Dougherty calls 'induction signatures', signs of magnetic fields that arise from electrical currents – driven by Jupiter's own magnetic field – flowing through the subsurface ocean. And they can contain clues to the nature of the ocean itself, such as its depth and salt content. It will take considerable work, however, to pick these 'signatures' out from the other magnetic fields within the system, including that generated by Jupiter, one originating from an immense sheet-like cloud of plasma encircling the gas giant, and another emerging from Ganymede itself. Each of these fields is constantly varying, complicating the search for the induction signatures considerably. "The way that I like to describe it, is it's like trying to find lots of needles in a haystack and those needles are changing shape and colour all the time," says Dougherty.

Exploring what lies beneath Ganymede's surface will be key to helping scientists get insights into worlds far beyond the realm of the Sun. "We're sure there are many other planets and moons out in our Universe which have a similar internal structure to Ganymede, and Ganymede allows us to better understand them and how they might have formed," explains Dougherty.



▲ Why does Callisto seem so different to the others? JUICE will investigate its surface and interior for clues

What lies beneath

It's not just at Ganymede that JUICE will be tackling big unresolved questions. Neighbouring Callisto, it would seem, is the odd one out of Jupiter's icy moons, in that its subsurface structure doesn't appear to be what planetary scientists call differentiated. "There isn't a solid core and there aren't the different layers in the interior that we're almost certain we have at

NASA/JPL, NASA/JPL/BROWN UNIVERSITY, GARY HINCKS/ SCIENCE PHOTO LIBRARY, NASA/JPL-CALTECH

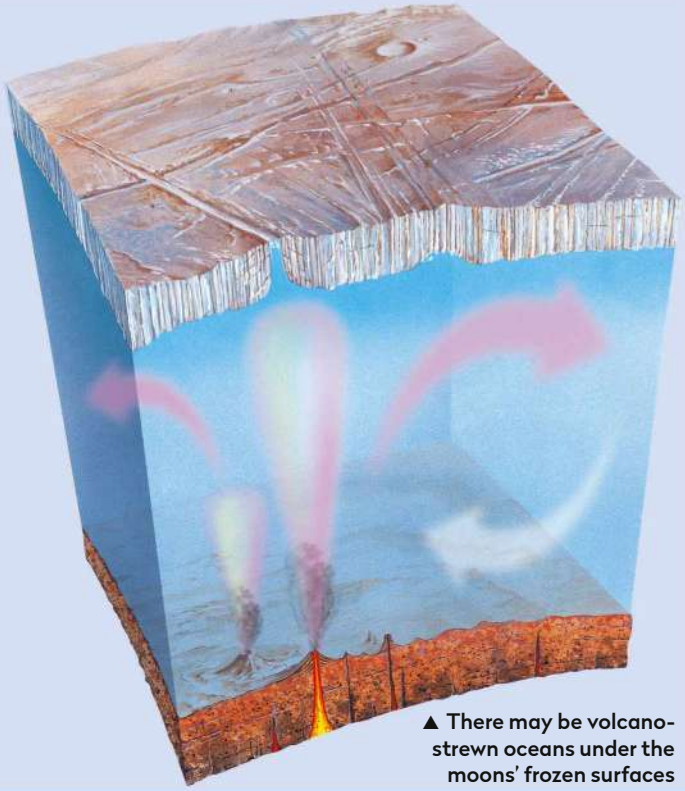
Life on the icy moons

Could habitats capable of supporting life be lurking under the crusts of Jupiter's icy moons?

There are only a few spots in our Solar System where large bodies of liquid water are either present or strongly suspected: Earth itself, and the interiors of some of the icy moons of the gas giants. Where there's liquid water on our own planet we almost always find lifeforms, and so the faraway oceans of the icy moons have become sites of immense interest in the search for life beyond our own world.

Among the forces thought to be heating the insides of Jupiter's largest moons is the gravitational push and pull between themselves, as well as with the giant planet – a process that warms them through friction. In the case of the icy moons, this heating is likely to be what is keeping their interior oceans liquid beneath icy crusts 15–150km thick.

At Saturn, the Cassini mission found evidence of possible hydrothermal vent activity in the subsurface ocean of its icy moon Enceladus. Is a similar thing happening at Ganymede, Callisto or Europa? On Earth such locations are often teeming with life. Could microbes be surviving in the depths of these Jovian moons? Though JUICE may not be able to answer for certain, it provides a great opportunity to begin that process.



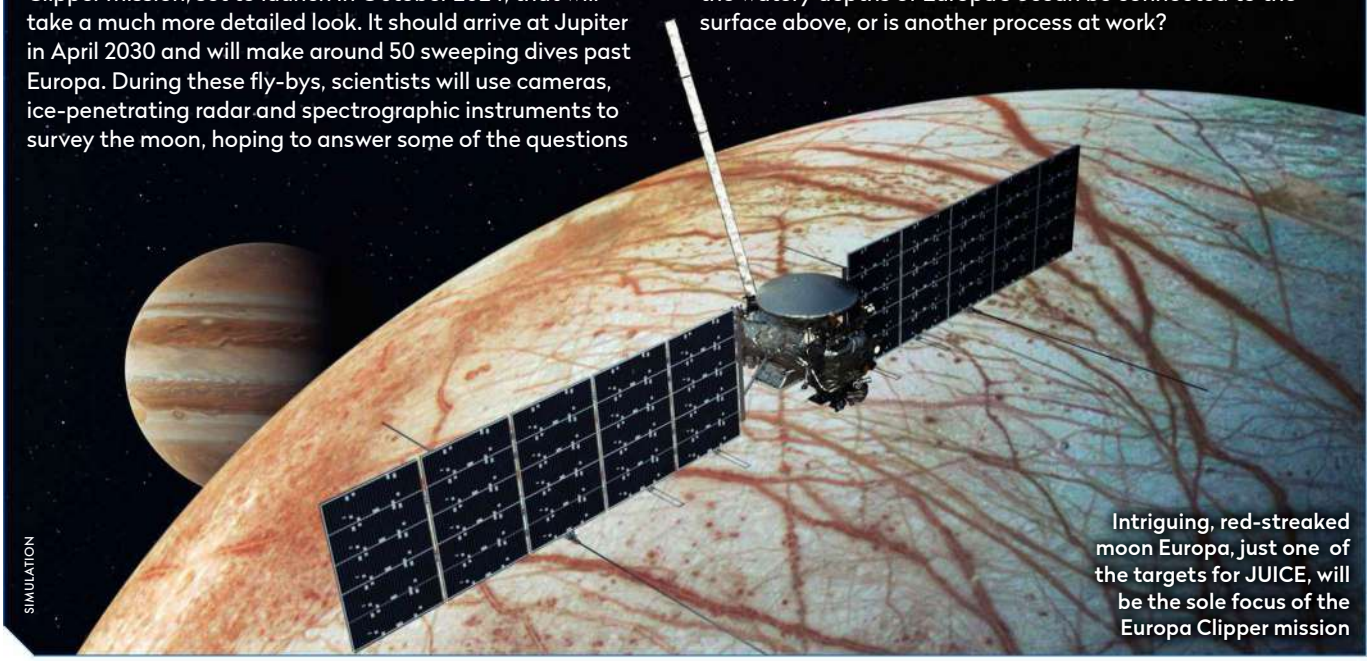
▲ There may be volcano-strewn oceans under the moons' frozen surfaces

Eyes on Europa

Next year, another mission – Clipper – will be heading towards Jupiter's icy moon Europa

Jupiter's fourth-largest moon, Europa, has long been the subject of discussion when it comes to environments that could be hospitable to life within our planetary neighbourhood. The roots of this interest lie predominantly in the data from the Galileo mission, which photographed the moon's enigmatically furrowed surface and uncovered evidence of a deep, liquid water ocean under its icy crust.

While JUICE *will* examine Europa, it will be NASA's Europa Clipper mission, set to launch in October 2024, that will take a much more detailed look. It should arrive at Jupiter in April 2030 and will make around 50 sweeping dives past Europa. During these fly-bys, scientists will use cameras, ice-penetrating radar and spectrographic instruments to survey the moon, hoping to answer some of the questions left by the Galileo mission, such as how thick Europa's crust is. Studies suggest it could be between a few kilometres and several tens of kilometres deep. Europa Clipper will also try to piece together the complex history of the relatively young Europan surface, which in some places appears to have cracked or melted and then re-frozen. The mission may even be able to reveal more about plumes of water vapour that have been detected by the Hubble Space Telescope – could the watery depths of Europa's ocean be connected to the surface above, or is another process at work?



SIMULATION

Intriguing, red-streaked moon Europa, just one of the targets for JUICE, will be the sole focus of the Europa Clipper mission

Europa and at Ganymede, and the question is why?" says Dougherty. "All of those moons formed at the same time. Why is the internal structure of Callisto so different?" JUICE will look for answers as it flies by.

While JUICE's focus will be on the icy worlds around Jupiter, it will also be examining the gas giant itself. Professor Leigh Fletcher, a planetary scientist based at the University of Leicester, will be coordinating JUICE's observations of Jupiter and says there is scientific instrumentation on board that "turns the dial to 11" compared to the capabilities of previous spacecraft. These include the Sub-millimetre Wave Instrument which is capable of observing the planet at sub-millimetre wavelengths of light.

"That's tremendously exciting for an atmospheric scientist," says Fletcher, "as it allows us to directly measure the winds and circulation high in the stratosphere, a feat that no previous mission has ever accomplished."

JUICE's orbit around the planet will also help it get detailed observations of the giant world of seething clouds and swirling storms. "There are long periods where we can monitor the atmosphere and magnetosphere to see how the Jupiter system changes and shifts over time," says Fletcher. "Snapshots are not enough to understand this complex system; we need to see how it changes."

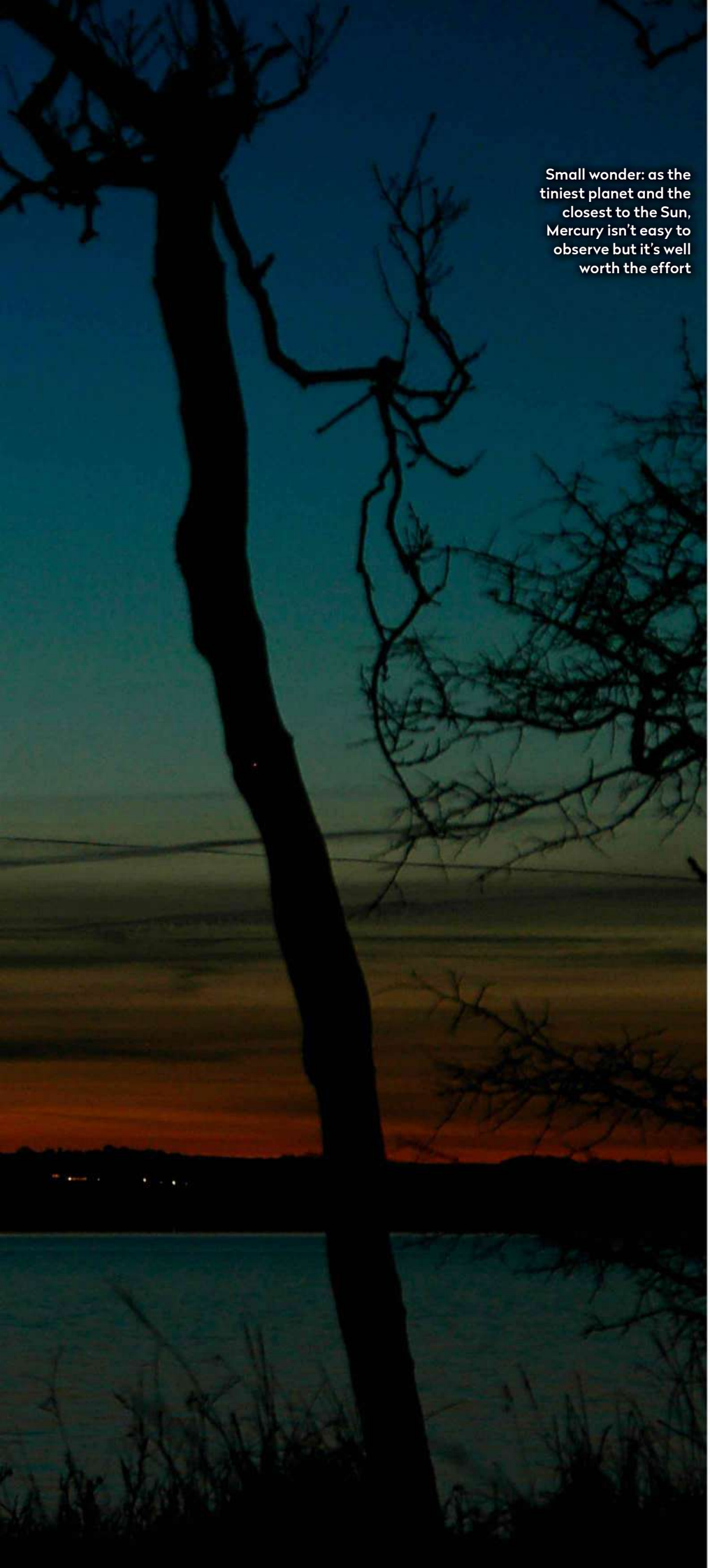
Built to last

To survive this incredible years-long adventure, JUICE has had to be designed to withstand the radiation environment found at Jupiter. "We have also designed an orbit that will keep us away from the worst of Jupiter's radiation belts – which is why we only venture in as close as Europa twice, and why we'll only be able to view Io from a distance," explains Fletcher.

But, he says, it's on our own planet where the mission has faced its biggest challenge, in the form of the global COVID pandemic. "Instrumentation developed in labs, institutions and industrial sites across the world had to be brought together by land, air and sea at a time when international travel and collaborative in-person working was facing a challenge like no other," says Fletcher. "When JUICE sits atop that Ariane 5, waiting to start the next phase of its journey, it will be testament to the sustained effort of thousands here on Earth, under challenges that no one foresaw when we were first dreaming of Europe's mission to Jupiter."

Will Gater is an astronomy journalist, author and presenter

Mercury returns to twilight



Small wonder: as the tiniest planet and the closest to the Sun, Mercury isn't easy to observe but it's well worth the effort

The inner wanderer graces our evening skies once again this month. **Charlotte Daniels** reveals when to look for Mercury, and what you'll be able to see

When most beginners start out in planetary astronomy, it's easy to default to the 'holy trinity' of Jupiter, Saturn and our neighbour Mars. Each boasts unique and relatively easy to observe features, from Saturn's rings and Jupiter's bands and Great Red Spot, to Mars's dusty surface. But why stop there? There are eight planets in our Solar System and many can be appreciated with beginner setups. The 'inner planets', Mercury and Venus, present new and exciting challenges to planetary astronomers. We explored Venus in last month's issue and now it's Mercury's turn for the spotlight.

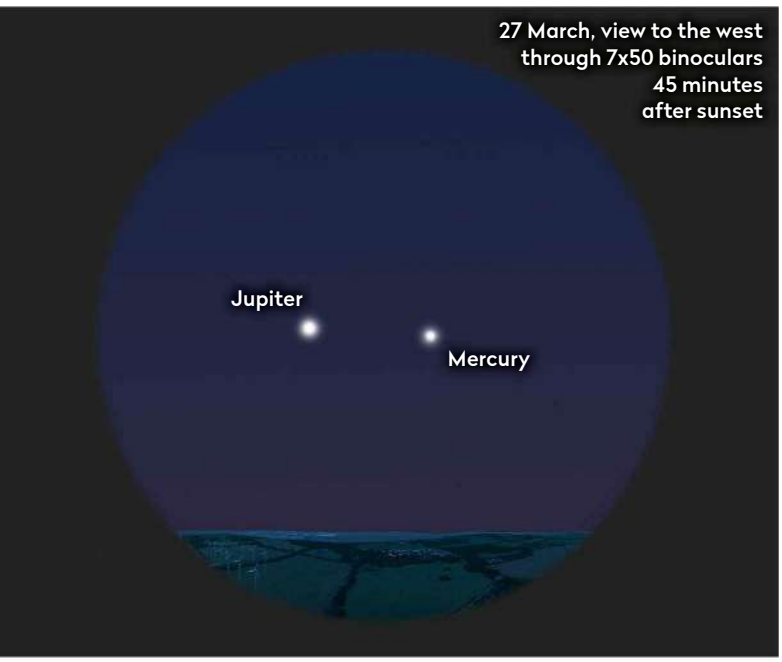
Due to its proximity to the Sun, extra care must be taken to observe Mercury safely, which adds to the challenge. There are particular times that are best to view this elusive, mysterious planet, and this April we can seize the opportunity. Get ready to enjoy one of the Solar System's unsung heroes.

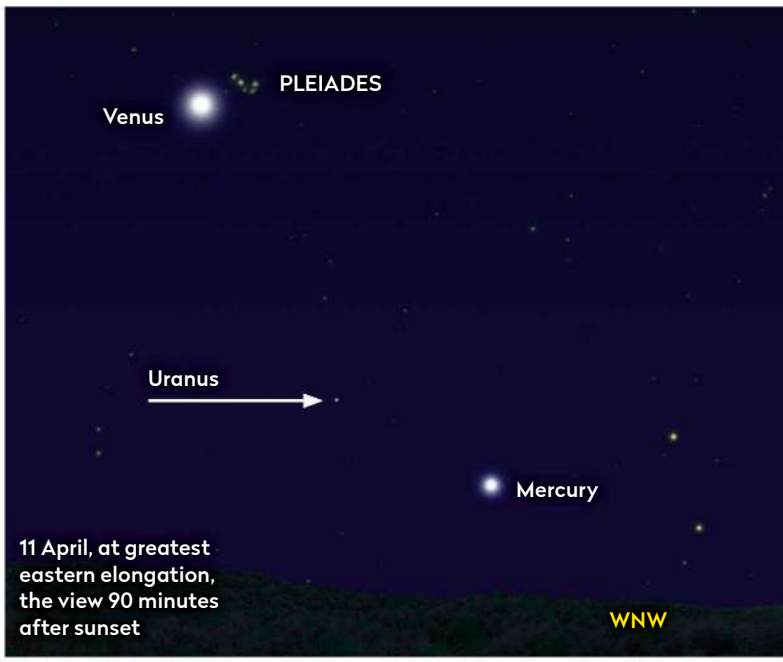
Following Mercury's path

The fastest planet in the Solar System, Mercury is named after the messenger of the Greek gods, renowned for speed. And time is certainly of the essence with this planet. To catch Mercury, we need to understand how its position relative to the Sun affects its visibility.

Mercury is 0.4 astronomical units (AU) away from the Sun and orbits at speeds ▶

WALTER MYERS/SCIENCE PHOTO LIBRARY





▲ **Left: Mercury sets alongside Jupiter, right after the Sun in late March. Right: there's more time at elongation, when a conjunction with Venus and Uranus also lies in store**

▶ of up to 47km per second, compared to Earth's relaxed pace of 30km per second. When it reaches its closest point to the Sun, Mercury is at its fastest and it then slows down slightly the further away it gets. As the innermost planet, it also has the shortest year, taking 88 Earth days to circle the Sun.

The gravitational influence of the Sun affects Mercury's orbit in other ways too. Mercury's journey around the Sun is highly 'eccentric', or egg-shaped: this means the distance between the two can vary from 46,000,000km to 69,000,000km. Moreover, just because Mercury's years are short, it doesn't mean its days are. In fact, it rotates so slowly on its axis that it completes one full rotation roughly every 59 Earth days. When we consider the speed that Mercury travels versus its slovenly rotational rate, we realise it doesn't experience conventional sunrises and sunsets to mark day and night times – one 'solar day' (a full day–night cycle) on Mercury is 176 Earth days!

Another thing that makes Mercury unique is its lack of moons. Anything likely to be bound to the planet is instead attracted by the strong pull of its host star.

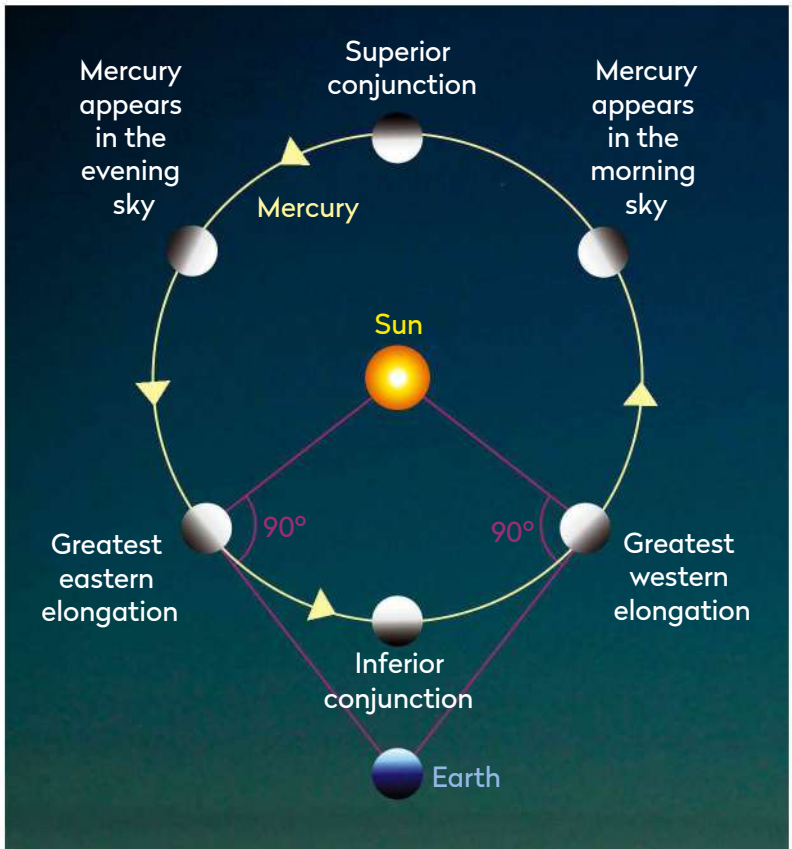
Elongations and conjunctions

Because Mercury is the planet closest to the Sun, it always appears close by and is often swallowed by our home star's glare. Mercury's appearances are therefore closely linked with our sunrise and sunsets, making it a morning or evening object, rather than something we can look for during later hours.

The best time to view Mercury is during greatest elongation, which next occurs on 11 April. This is when Mercury is farthest from the Sun, so it is placed far either to the east or west side of it (known as eastern and western elongations, respectively). What we'll have on 11 April is a greatest eastern elongation event. This places it a little further from the Sun's glare and at its highest altitude, helping us to view it. The angular separation due to elongation can vary from roughly 20° to 28°, the equivalent of one handspan to three clenched fists next to each other, held at arm's length. When positioned at the eastern side of the Sun, Mercury appears in our evening skies; when at the western side it appears in early morning skies. When it makes its evening appearances, the planet is seen above the western horizon shortly after sunset in twilight (as it will be around 2–15 April), and as a morning planet it appears in the east shortly before sunrise (as it will be around 27–31 May). A very clear eastern horizon will be needed.

These elongation events mark Mercury's best and safest observing periods. Because Mercury is closest to the Sun, elongations are regular and happen every ▶

▼ **The best time to catch the planet is at eastern or western elongation, when its orbit brings it far enough from the Sun's glare**



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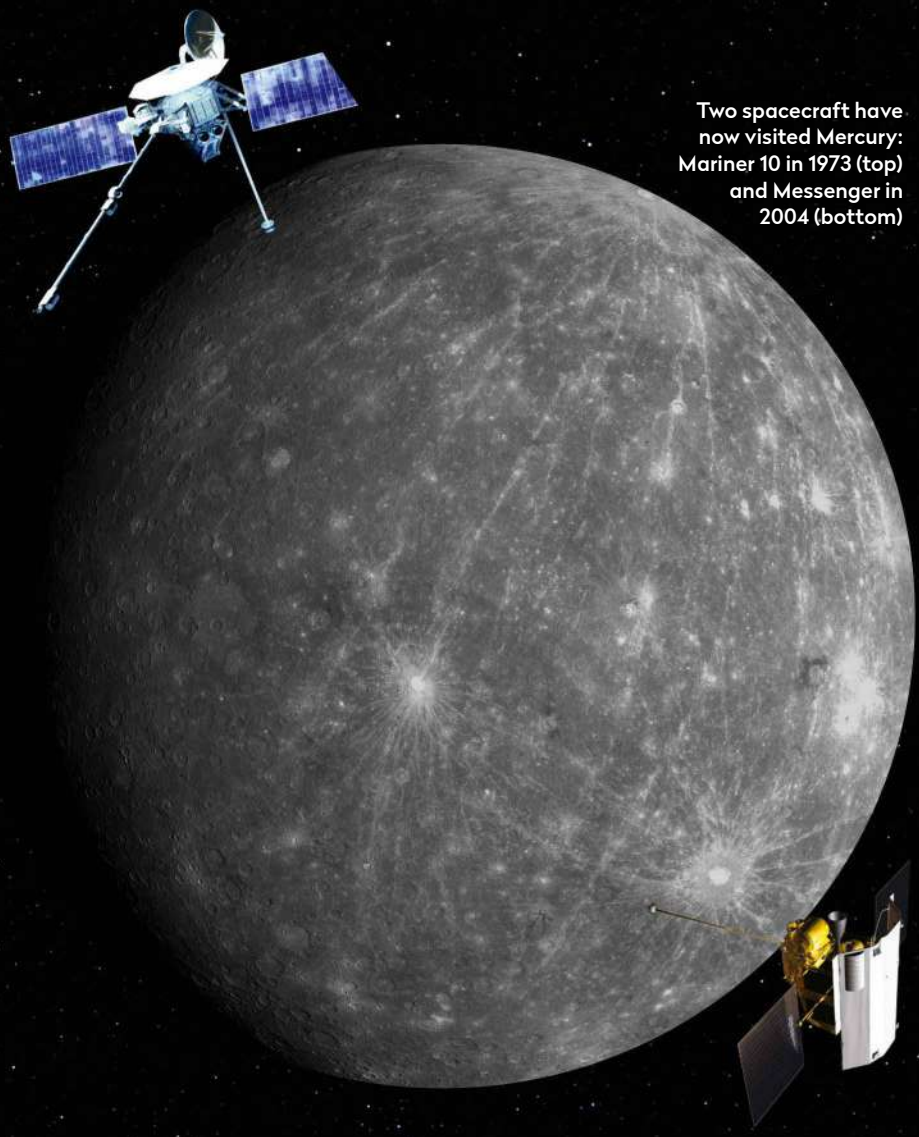
Unravelling Mercury's mysteries

What do we know about the innermost planet, and how has humanity explored it?



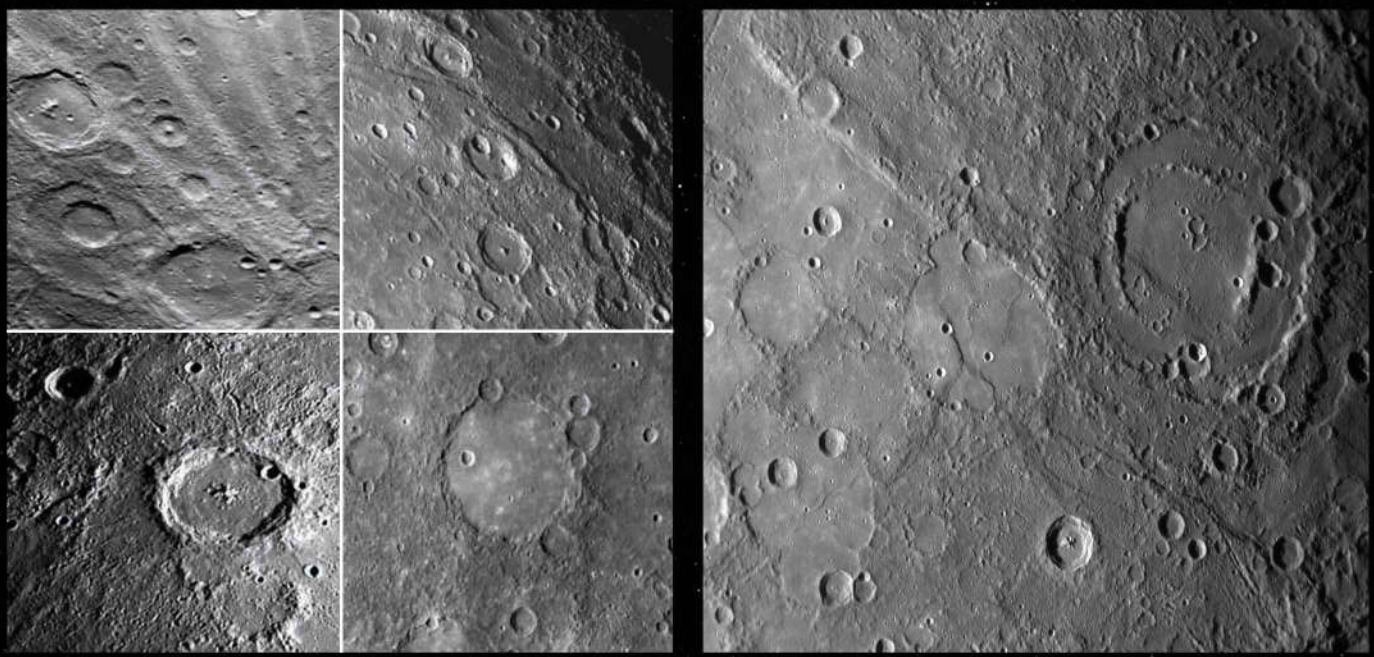
Two spacecraft have now visited Mercury: Mariner 10 in 1973 (top) and Messenger in 2004 (bottom)

Mercury is the smallest planet, barely larger than our own Moon at a mere 2,440km in diameter. As it's also the closest to the Sun, you'd be forgiven for thinking it's the hottest planet in the system, but that's not the case due to a thin 'exosphere' of oxygen, hydrogen, sodium, helium and potassium. Lack of heat retention means its surface temperature varies from almost 450°C in the day to –180°C at night. Despite being further away, Venus reaches temperatures up to 470°C thanks to its thick atmosphere.

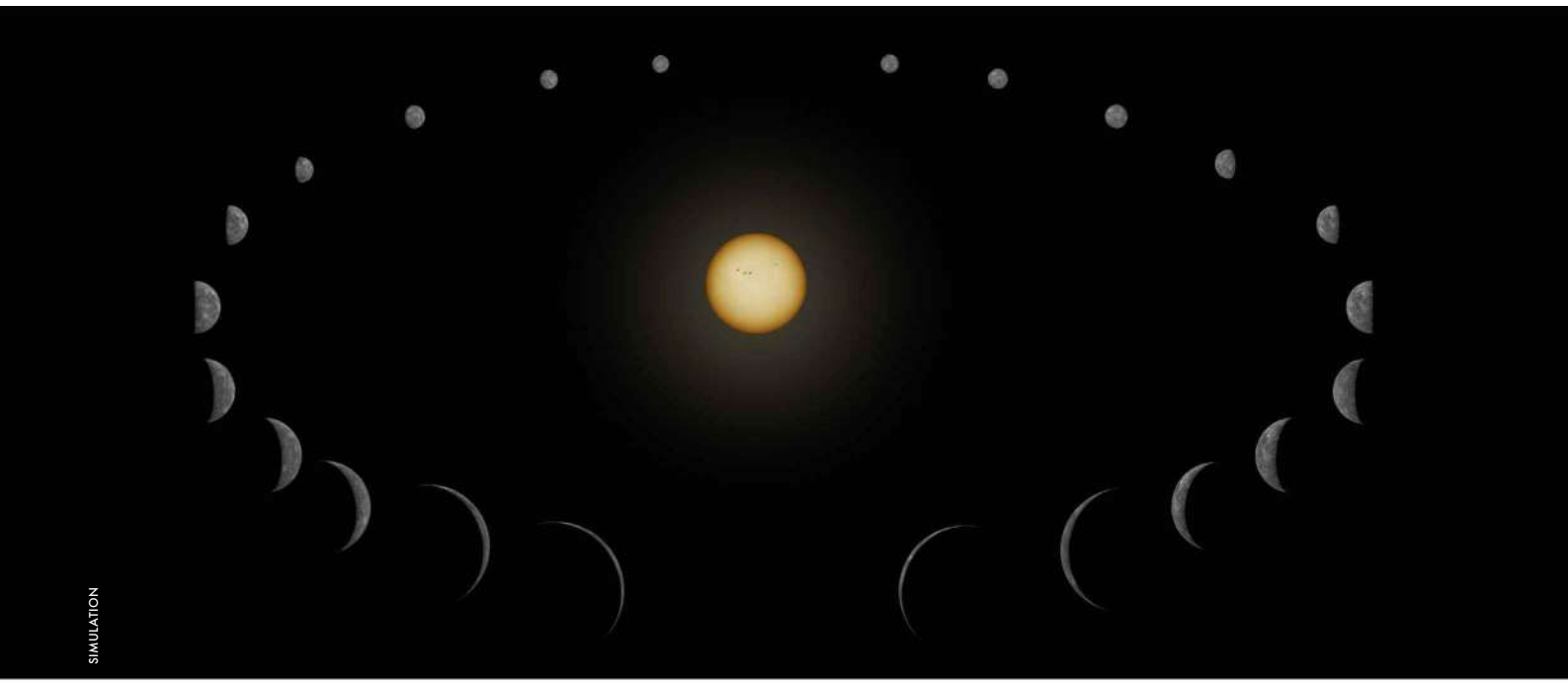
Mercury is a 'terrestrial' or rocky planet, displaying a cratered surface that resembles Earth's Moon. Underneath lies a large metallic core, mantle and crust. Thanks to a minor axial tilt (2°), Mercury doesn't experience seasons.

To date, two NASA missions have visited Mercury. Mariner 10 launched in 1973 and flew past the next year, observing the cratered surface. Messenger followed in 2004 and was the first to orbit, in 2011. Discoveries included ice at the poles and the presence of relatively new fault 'cliffs' on the surface, hinting at tectonic activity. These fault lines suggest Mercury is contracting and 'shrinking' as the molten interior cools, warping the surface. Over its lifetime, Mercury is estimated to have shrunk by almost 16km (10 miles).

The European Space Agency now has BepiColombo winging its way over, expecting to arrive in 2025. It will take a closer look at the magnetic field, core and polar ice, to learn more about Mercury's early life.



▲ Rays, ridges, craters and basins were imaged by NASA's Mariner 10 (left) in the 1970s before the Messenger spacecraft in 2011–15 took tens of thousands of images, revealing far more detailed pictures (right) of fault lines, double-ringed craters and other tectonic activity



SIMULATION

▲ **Just like the Moon, Mercury exhibits a range of phases as viewed from Earth throughout the year**

▶ 3–4 months. It's at this point that the planet will appear highest above the horizon, placing it at the best position to observe as it will be clear of light pollution and least affected by atmospheric seeing. Mercury reaches this point on 11 April, making this a great time to start looking for it. Even so, it never strays far from the Sun, with this elongation only reaching a maximum angular separation of 19.5°.

Inferior and superior conjunctions are specific to the inner planets, and mark times when we can't view Mercury. Inferior conjunctions refer to times when Mercury or Venus pass directly between Earth and the Sun, positioning them in front of the Sun at sunrise and sunset, so they are lost in its glare. Superior conjunctions refer to times when these two planets are positioned on the opposite side of the Sun to Earth, again making them unviewable. Mercury next reaches inferior conjunction on 1 May and superior conjunction on 1 July.

So what can we observe when the time is right for Mercury? Despite its challenges, the planet can be appreciated with and without a telescope. If viewed with the naked eye, it tends to appear as a bright point object, similar in appearance to a star, with its magnitude varying from as bright as mag. –2.8 to a dim mag. +7, when it is only visible through binoculars or a telescope. If close to the horizon, atmospheric turbulence might make it appear to 'twinkle' like a star. However, if you take some time to study it unaided you will detect a subtle, rosy, golden tinge that singles it out from the starry background. Mercury's apparent diameter, depending on its distance from Earth, can range from 4.5 arcseconds at apogee to 12.9 arcseconds at perigee. A pair of low-powered binoculars will help you locate the planet, particularly at times when it is dimmer.

Because Mercury is often viewed against brighter skies, a telescope will help you locate it. Again, you'll want clear western or eastern horizons (depending on when you're viewing). With a 3-inch scope you'll

▼ **Left: from afar Mercury is a tiny but distinct dot in the sky. Right: even with a modest telescope you can see much more**

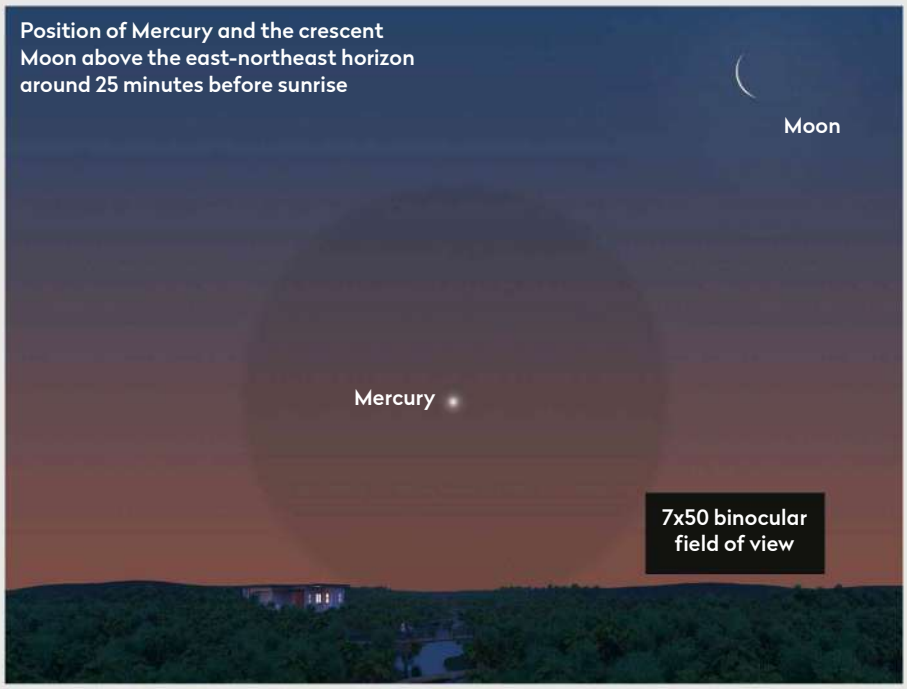
PETE LAWRENCE X 4

What's next for Mercury?

Keep an eye out for more chances to see the planet in the months ahead

After April, Mercury goes quiet for a little while. On 1 May there's an inferior conjunction, where it's positioned directly between the Sun and Earth. This position in the morning sky will make it almost impossible to observe as not only is it hidden in the Sun's glare, but it appears as a thin crescent so is hard to pick out even with a telescope. On 29 May it will reach greatest western elongation.. On 16 June, it will appear close to a 3%-illuminated Moon. July and August will prove disappointing for Mercury, as at best it will make brief appearances very low on the horizon and in light evening skies.

September will see Mercury's greatest western elongation on the 22nd, meaning the planet will make another welcome appearance, rising 100 minutes before sunrise and climbing to 10° above the eastern horizon. Make the most of the planet looking bright in early morning skies during the first week of October before it lurks low on the horizon after sunset for much of November. By 31 December, Mercury will make a final brief appearance in the morning, just above the southeast horizon before sunrise.


Position of Mercury and the crescent Moon above the east-northeast horizon around 25 minutes before sunrise
Moon
Mercury
7x50 binocular field of view

▲ One of the best sights will be Mercury's pairing with a sliver of a Moon early on 16 June

start to appreciate Mercury's phases. Although the planet is unobservable at its full phase during superior conjunction and at its new phase at inferior conjunction, even in the short windows of opportunity in between you will notice changes in its phases.

While we won't see craters, on nights of exceptional seeing and minimal turbulence, we may discern some surface details with larger-aperture telescopes. With all planetary astronomy, seeing conditions will greatly affect observations. Therefore, providing it's safe to do so, try to catch the planet at its highest possible altitude, at a minimum of one hour outside of sunrise or sunset times.

Because it is so closely bound to our Sun, it is imperative when viewing Mercury to avoid the risk of viewing the Sun directly. Never try to find Mercury in broad daylight or during conjunctions; aim instead for elongation events. Ascertain the sunrise or sunset time on the day of observation and use a sky guide to establish the angular separation of Mercury from the Sun. Ensure that the full disc of the Sun is behind the horizon at the time of viewing.

When to observe Mercury

You can catch Mercury in the evening sky and close to Jupiter on 27 March, less than half a degree apart from Jupiter's southeastern limb. It will be a bright mag. –1.3, comparable to Jupiter at mag. –1.59, and great to view whether with the naked eye or through a telescope. Be quick, however, as it will set an hour after sunset, which is at around 19:25 BST (18:25 UT). A clear western horizon is needed.

April is a great time to view Mercury as it meets all the criteria required to enjoy this planet: it's at its furthest distance from the Sun and relatively high above the horizon at sunset, meaning we can catch it once the Sun is safely out of the way. Mercury is best at the start and middle of the month, when its magnitude will vary from mag. –1.0 to mag. +1.2 over the first two weeks – very bright to the naked eye, providing you have good horizons. It will be at greatest elongation east on 11 April, reaching 16° altitude and positioned close to both Uranus and Venus at sunset. It will set two hours later, giving us plenty of time to see it. The remainder of April will see Mercury dim as its peak altitude gets lower. By the month's end, it is expected to be mag. +4.3 and only 6° above the western horizon at sunset.

From the end of March to the end of April, those with telescopes can observe Mercury wane from an almost full 91%-lit disc on 28 March to 7%-lit on 24 April. Naturally, as the disc becomes smaller the planet dims and therefore becomes harder to make out, in addition to sinking further towards the horizon.

Whether you're looking with the naked eye or using magnification, if you've never taken the time to appreciate Mercury before, now's the perfect time.

▶ **For more details about observing Mercury this month, turn to page 48**

Charlotte Daniels is an experienced practical astronomer and astrophotographer

COSMOLOGY CRASH COURSE

Does the Universe have an edge?

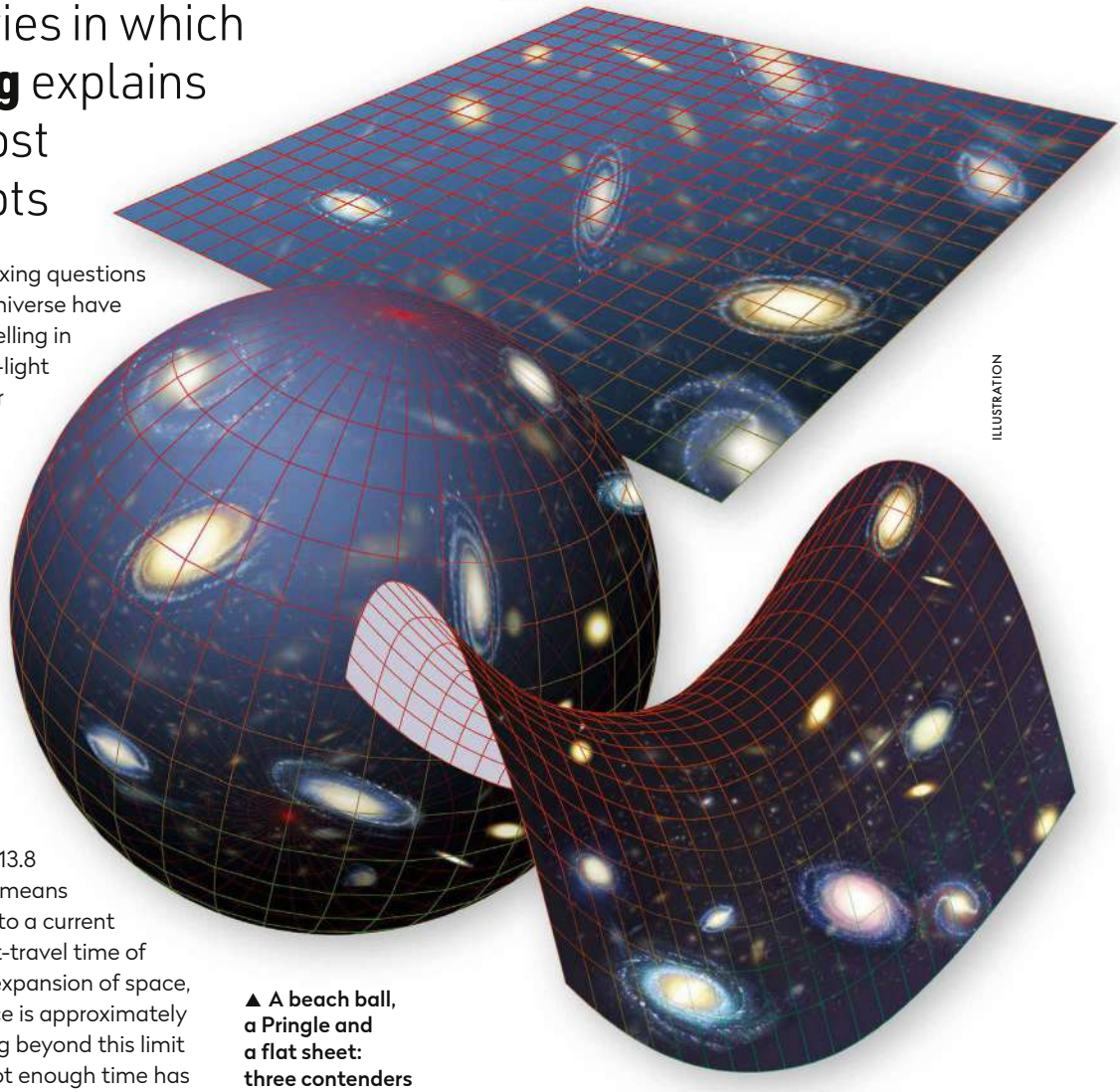
Part 4 of our series in which **Govert Schilling** explains cosmology's most complex concepts

It's one of the most perplexing questions in cosmology: does our Universe have an edge? If you keep travelling in an imaginary faster-than-light spaceship, would you ever arrive at some boundary, unable to go any further? And if so, what lies beyond? It's all very hard to imagine. Then again, an infinite Universe is just as difficult to wrap your head around. After all, there must be something that space is expanding into, right?

Let's start with a related but easier-to-grasp concept: our Universe has an *apparent* edge, called the cosmological horizon. The light emitted right after the Big Bang has been travelling for 13.8 billion years through space. This means we can only see the Universe up to a current distance corresponding to a light-travel time of 13.8 billion years. Thanks to the expansion of space, this so-called co-moving distance is approximately 45 billion lightyears, and anything beyond this limit is unobservable to us because not enough time has elapsed since the birth of the Universe for light from these remote regions to reach our telescopes.

But, just like the familiar horizon seen by sailors on the ocean, this cosmological horizon is not some real, physical boundary. And as the ocean stretches beyond the sailor's horizon, so too does space stretch beyond our *observable* Universe. There's no reason why there can't be galaxies at these extremely large distances; they're just invisible to us, no matter how powerful our telescopes are.

But knowing the Universe goes on beyond 45 billion lightyears still doesn't tell us whether it's finite or infinite. But one thing's for sure: the Universe does not have an edge. There's no physical boundary – no wall, no border, no fence around the edges of the cosmos.



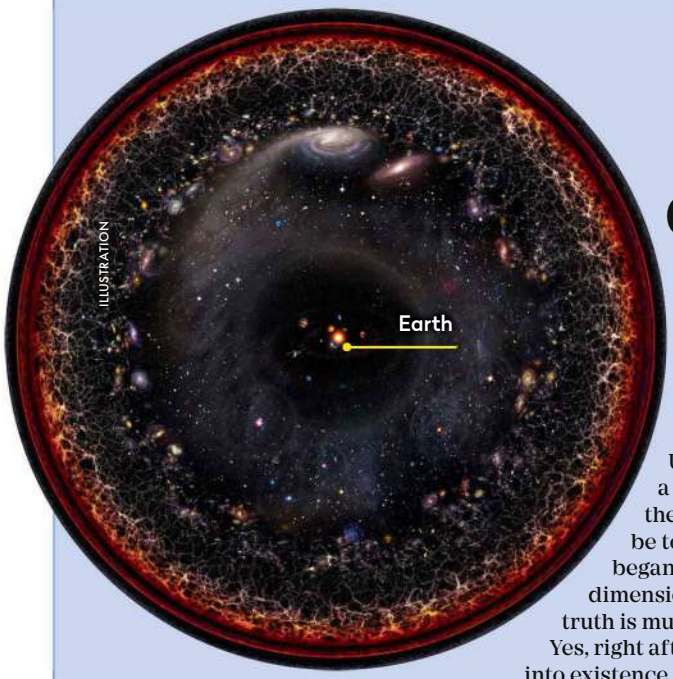
ILLUSTRATION

▲ **A beach ball, a Pringle and a flat sheet: three contenders for the shape of the Universe**

Curve appeal

This doesn't necessarily mean that the Universe is infinitely large though. In principle, we could live in a finite Universe, provided that three-dimensional empty space is geometrically curved in a particular way – a distinct possibility according to Albert Einstein's theory of general relativity.

MARK GARLICK/SCIENCE PHOTO LIBRARY, PABLO CARLOS BUDASSI, KRISCOLE/ISTOCK/GETTY IMAGES



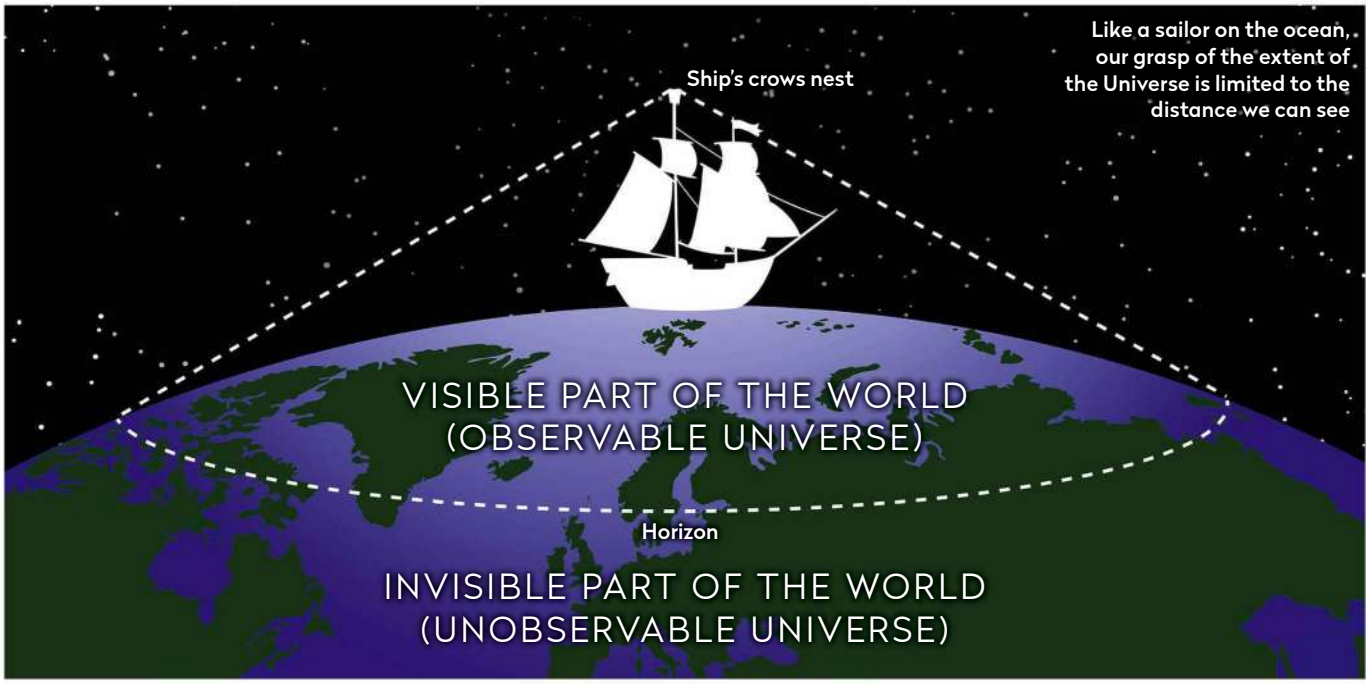
▲ The observable Universe, from our nearest stars out to the furthest galaxies and the microwave background beyond

Once infinite, always infinite

Whether tiny, hot nugget or unimaginably huge cosmos, space goes on forever

In many popular astronomy books, you may read that our Universe was as small as a grapefruit right after the Big Bang. Or you may be told that the Universe began as an infinitesimal, dimensionless point. In fact, the truth is much weirder.

Yes, right after the Universe came into existence, some 13.8 billion years ago, space was incredibly more 'compact' than it is now, and both the temperature and the matter density of the Universe were incredibly high. But if our present Universe is infinitely large, it must always have been infinitely large, even at the primordial epoch when all spatial distances were, say, one billion times as small as they are now. After all, infinity divided by one billion is still infinity. What you can say is that our observable Universe – the 45-million-lightyear radius sphere that we can study at present – was once compressed into an incredibly tiny volume. But even back then, an infinite Universe just would've gone on forever beyond the 'edge' of this imaginary grapefruit.


Like a sailor on the ocean, our grasp of the extent of the Universe is limited to the distance we can see
Ship's crows nest
VISIBLE PART OF THE WORLD
(OBSERVABLE UNIVERSE)
Horizon
INVISIBLE PART OF THE WORLD
(UNOBSERVABLE UNIVERSE)

If the Universe has what's known as positive curvature, it would be like the curved surface of a beach ball, but rather than a 2D surface, it's 3D space. It is finite – if you were living in this flattened version of the cosmos, you wouldn't need an infinite amount of paint to cover your 2D Universe – yet there is no boundary or edge to the surface itself.

In contrast, a negatively curved Universe would be a higher-dimensional version of a Pringle – curving upwards along one axis and downwards along the other – while a flat Universe would resemble a piece of paper. Both of these versions would stretch out infinitely.

Cosmologists have tried to measure the large-scale curvature of space over the past few decades, and the most recent results combined with theoretical arguments seem to indicate that we live in a geometrically flat Universe. On the one hand, that's convenient as our brains aren't very good at imagining large-scale space curvature – even here we've had to describe our 3D Universe in 2D terms. On the other hand, this means that our Universe is infinitely large, and that our observable Universe – the part within our cosmological horizon – is only an infinitesimally small fraction of an unimaginably large whole.

Govert Schilling's book *The Elephant in the Universe* is published by Harvard University Press

In case you were wondering how our infinite, boundless Universe is able to expand, return once again to our 2D analogy. If you saw the grid size on a piece of graph paper growing, you would justifiably conclude that the paper is expanding. If the paper was so large that you couldn't see the edge, you'd still draw the same conclusion, even though the piece of paper could also be infinitely large. The same is true for an infinite Universe. After all, infinity times two is still infinity!

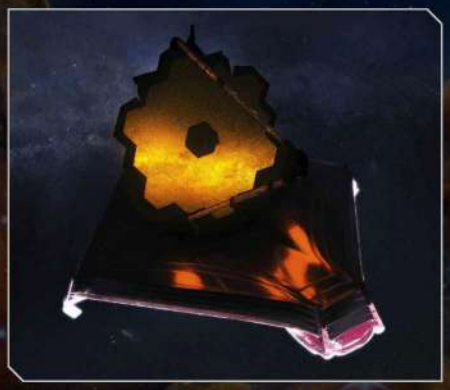
BBC Sky at Night MAGAZINE

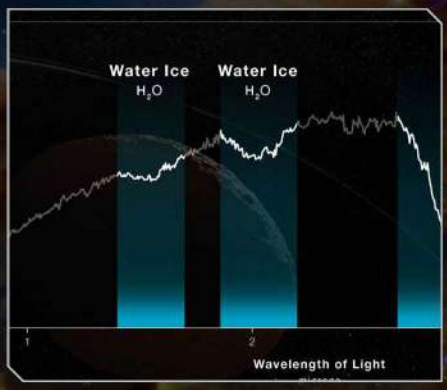
MASTERCLASS

THE JWST SERIES

Join host and editor Chris Bramley for a three-part series of online masterclasses on the greatest space telescope humanity has ever launched, the James Webb Space Telescope (JWST), as it nears the end of its first full year of operations. The three talks from expert speakers will explain how its stunning images are created, how the telescope was built and launched, and the ground-breaking scientific discoveries that are coming from its observations.

Book each Masterclass individually for £15 each, or save 20% and book all three at once for £36. Registrants will also receive a link to view a recording of each talk after it has aired





Masterclass 1

JWST: the Images

Joe de Pasquale

Lead Image Processor, Space Telescope Science Institute, Baltimore, USA

Join us as we discover how some of JWST's most captivating images to date are created, exploring how black-and-white data is translated into the visible spectrum from instruments that detect infrared light.

Thursday 30 March, 7pm BST

Masterclass 2

JWST: the Telescope

Dr Olivia Jones

STFC Webb Fellow and Astrophysicist, JWST MIRI Instrument Team

We look at how this $10bn space telescope was constructed and successfully made a 1.5-million-kilometre journey through space, as well as the UK's key involvement in building JWST's MIRI instrument.

Thursday 4 May, 7pm BST

Masterclass 3

JWST: the Science

Dr Henrik Melin

STFC Webb Fellow and Planetary Scientist, University of Leicester

Delve into the major discoveries made in JWST's first year of observations, across the early Universe, galaxies, stars and exoplanets, and where its breakthroughs could lead us in our quest to understand the Universe.

Thursday 25 May, 7pm BST

NASA/ESA/CSA/STSCI/ IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI) ALYSSA PAGAN (STSCI) ANTON M. KOEKEMOER (STSCI), ADRIANA MANRIQUE GUTIERREZ/NASA ANIMATOR, NASA/ESA/CSA/STSCI/MEGAN REITER (RICE UNIVERSITY) WITH IMAGE PROCESSING BY JOSEPH DEPASQUALE (STSCI) ANTON M. KOEKEMOER (STSCI), NASA/ESA/CSA/LEAH HUSTAK (STSCI)/SCIENCE: NOEMÍ PINILLA-ALONSO (FSI/UCF) IAN WONG (STSCI) JAVIER LICANDRO (IAC)

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BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

APRIL 2023

VENUS AND THE PLEIADES

Venus makes a close pass of the Pleiades open cluster this month – a photogenic conjunction not to be missed!

MERCURY RISING

Follow the elusive world as it climbs in the evening sky

OUT LIKE A LIGHT

Watch the star Alniyat vanish behind the Moon

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Spy the Moon's Spitzbergen mountains
- A favourable peak for the Lyrids
- Venus and the Moon in the daylight sky

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

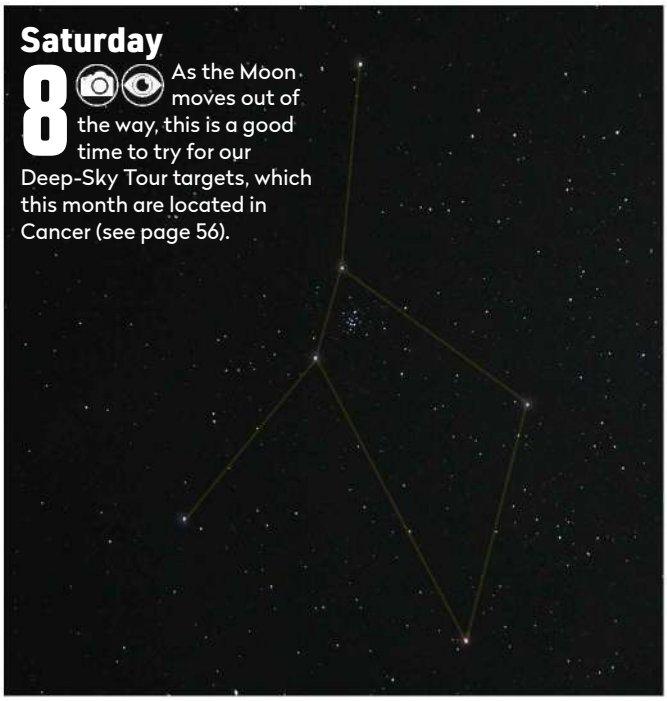
For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

APRIL HIGHLIGHTS

Your guide to the night sky this month

Saturday 8

As the Moon moves out of the way, this is a good time to try for our Deep-Sky Tour targets, which this month are located in Cancer (see page 56).



Sunday ▶ 9

As the sky darkens this evening, mag. –3.9 Venus is south of the Pleiades open cluster. Closest approach is tomorrow evening when they appear 2.7° apart.

Tuesday 11

Mercury reaches greatest eastern elongation, when it's visible 19.5° from the Sun in the evening sky after sunset.

Thursday 13

Venus is positioned between the Pleiades and Hyades open clusters today.

Friday 14

Mag. +1.2 Mars sits 9.5 arcminutes from mag. +3.0 Mebsuta (Epsilon (ε) Gemininorum) this evening.

Saturday 15

A good day to align sundials, as the difference between the apparent and mean Sun align today (equation of time = zero). The Sun is due south at midday UT. See the Sky Guide Challenge on page 55 for details.

Tuesday 18

Venus is north of the Hyades. With the Moon out of the way, this is a great opportunity to grab a photo of Venus, the Hyades and Pleiades together.

Friday 21

A tricky trio is visible low above the west-northwest horizon after sunset: Mercury, Uranus and a slender 3%-lit waxing crescent Moon.

◀ Saturday 22

The waxing crescent Moon is near the Pleiades tonight.

It sets around 23:50 BST (22:50 UT), making this year's Lyrid meteor shower, which peaks tonight, favourable.

Tuesday 25

This evening and into tomorrow morning, just before they set, the 32%-lit waxing crescent Moon sits close to mag. +1.3 Mars.

Thursday 27

This evening's first quarter Moon sits 3° north of the Beehive Cluster, M44.

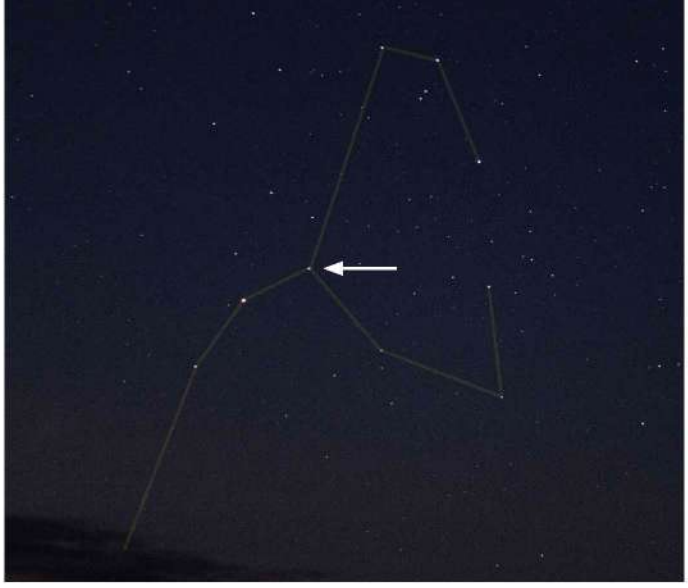
Friday ▶ 28

Although not ideally placed, a telescope view of the Moon this morning will show a good presentation of this month's Moonwatch target, Montes Spitzbergen (see page 52).

PETE LAWRENCE X 7

Monday ▶ 10

The 83%-lit waning gibbous Moon occults mag. +2.9 Alniyat (Sigma (σ) Scorpii) around 03:35–04:30 BST (02:35–03:30 UT). The Moon will be less than 2° from mag. +1.0 Antares (Alpha (α) Scorpii) at this time.



◀ Wednesday 12

Lunar libration currently favours the Moon's northern limb, with favourable phase lighting revealing many of the jumbled craters located in this region.

Thursday ▶ 20

As the Moon moves out of the glare of the Sun over the next few evenings, libration will favour the eastern limb.

Sunday 23

The Moon and Venus appear close at sunset, separated by less than 3°. Earlier, at 12:30 BST (11:30 UT), the pair are 0.7° apart.

Sunday 30

Minor planet 7 Iris reaches opposition, when it will be shining at mag. +9.6 against the stars of Libra.

Family stargazing

Venus will appear near the beautiful Pleiades open cluster this month. This is conveniently placed and timed in the evening sky. Closest approach is on 10 April, but the approach and separation can be seen on the days before and after this. If it's clear, head outside and suggest making a drawing of the encounter based on what can be seen with the naked eye. The Pleiades are also known as the Seven Sisters, so use this opportunity to ask how many of the cluster stars you can see.

www.bbc.co.uk/cbeebies/shows/stargazing

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

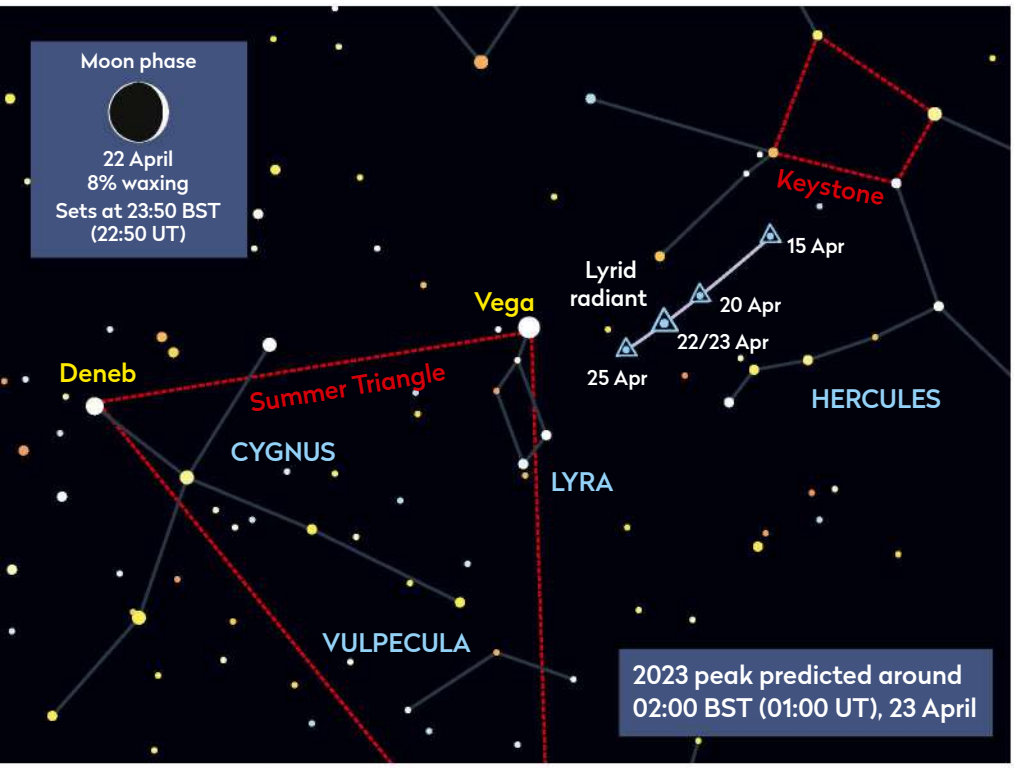
Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/10_easylessons** for our 10-step guide to getting started and **bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The top sights to observe or image this month



◀ The conditions for this year's Lyrid meteor shower are favourable thanks to an early-setting waxing crescent Moon

DON'T MISS

The Lyrids

BEST TIME TO SEE: 14–30 April, peak on 22/23 April. Darkness between 22:30–03:30 BST (21:30–02:30 UT)

This year is looking good for meteor showers, despite getting off to a poor start with an underwhelming showing from the January Quadrantids. That was down to the presence of an almost full Moon around the shower's peak period.

Meteor showers are awkward in the world of astronomy. Although you can predict with a reasonable degree of accuracy when a shower's peak period of activity will occur, you cannot specify exactly when and where individual meteor trails will be seen. The number of trails expected during a shower's peak period is expressed by a quantity known as the Zenithal Hourly Rate (ZHR). This is a value primarily used to compare the activity rates between meteor showers.

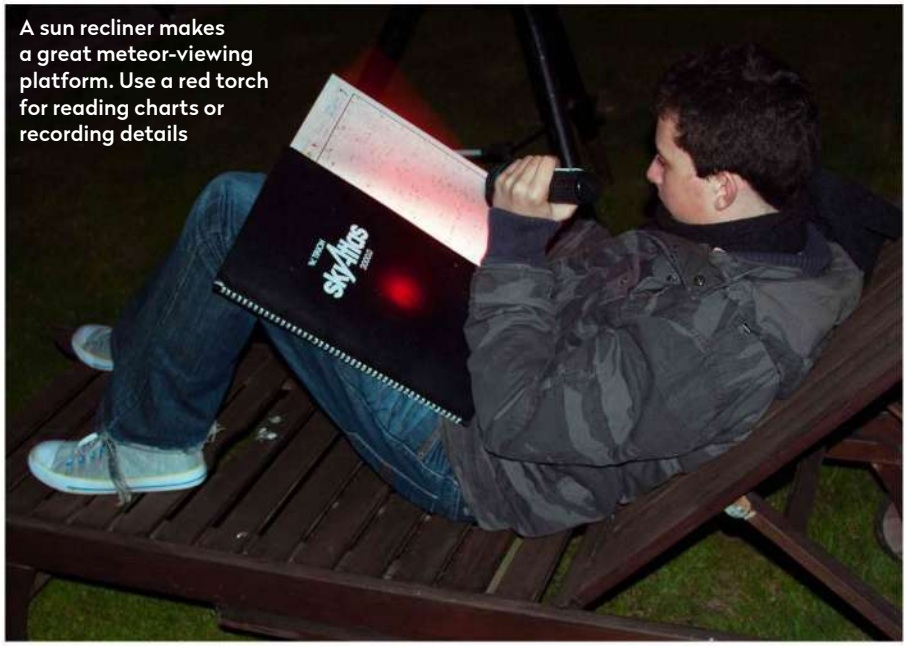
The ZHR figure is often misunderstood and needs to be considered in context with local conditions. A ZHR value is calculated by noting the number of shower meteors seen in a set period of time. Shower trails emanate from a small area of sky known as the shower radiant. The ZHR value assumes perfect placement of the radiant, overhead at the zenith. Among other things, it also assumes perfect skies and your ability to see the entire sky in one view. In practice, you'll be lucky if even one of these conditions is met. As a result, the experienced visual hourly rate (VHR) will be less than the shower's quoted ZHR.

The VHR isn't commonly described, for good reason. It varies depending on sky quality, date and time of day. Consequently, it would need to be calculated continually in real time. The Moon has a big effect on a shower's ZHR to VHR conversion, lowering the VHR considerably. The same occurs when the altitude of the shower radiant drops.

This month sees the peak of the Lyrid meteor shower. Activity occurs between 14 and 30 April, with the peak predicted for the night of 22/23 April. Although the shower has a modest peak ZHR of 18 meteors per hour, it does have a number of factors in its favour.

From the UK, the radiant height approaches 70° just before astronomical darkness ends on 23 April. In addition, the Moon will be new on 21 April and will not interfere. This creates a very favourable situation for 2023's Lyrid peak.

Lyrid meteors appear to emanate from the radiant position, southwest of bright Vega (Alpha (α) Lyrae). This makes it particularly easy to trace a trail back to see whether it did indeed come from the radiant location. Technically, the radiant sits in Hercules at the time of peak activity.

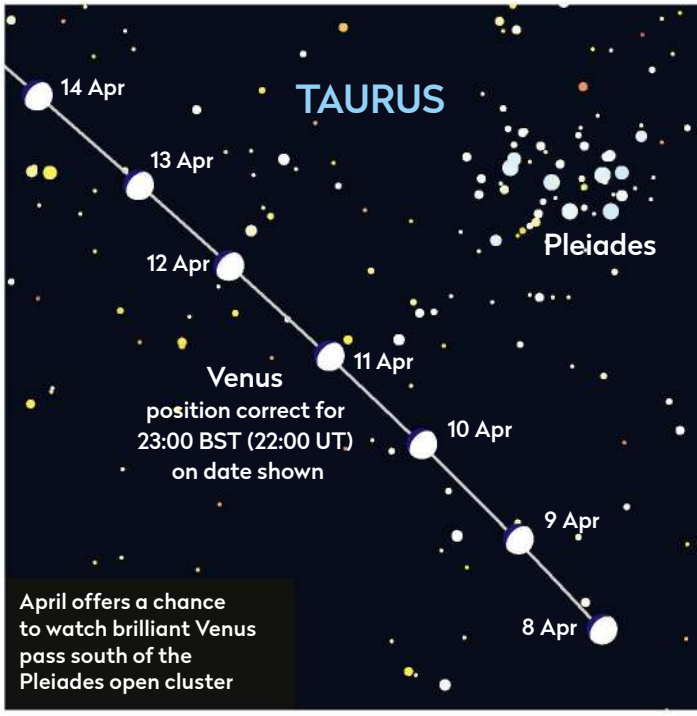


A sun recliner makes a great meteor-viewing platform. Use a red torch for reading charts or recording details

ALL PICTURES: PETE LAWRENCE

Venus and the Pleiades

BEST TIME TO SEE: Early evening, 8–14 April



April offers a chance to watch brilliant Venus pass south of the Pleiades open cluster

Venus passes south of the Pleiades during April, creating an opportunity to take a stunning photograph of the bright planet and beautiful open cluster. The best time to see the passage is on the evenings of 8–14 April. Their closest approach occurs on the evenings of 10 and 11 April, when Venus passes 2.7° south of the cluster's centre. Although the evening twilight expands rapidly throughout April, it should still be possible to see the closest part of this encounter against dark skies, the pair appearing over 10° above the west-northwest horizon.

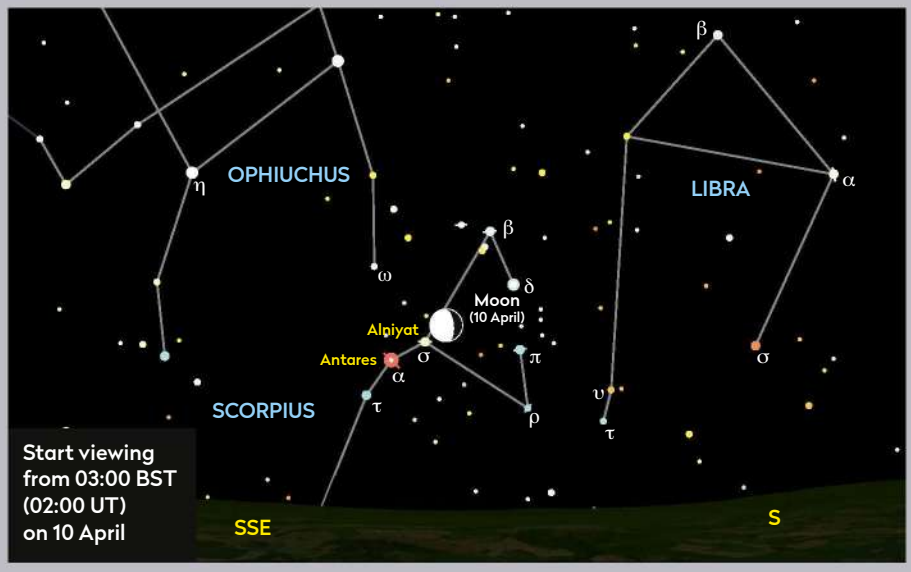
Compromised by twilight, the Pleiades is visited by a thin waxing crescent Moon on the evenings of 21 and 22 April. On 21 April, the 3%-lit waxing crescent Moon sits 8.7° below and slightly to the right of the Pleiades as seen from the UK. On the evening of 22 April, the now 8%-lit waxing crescent Moon sits 5.8° east (left and slightly up as seen from the UK) of the cluster's stars.

During the day on 23 April, the 12%-lit waxing crescent Moon is located 44 arcminutes north of mag. –4.0 Venus, making this a great time to try to find the pair during daylight hours. Their closest approach is around 13:00 BST (12:00 UT), when the pair will be approximately 50° up, above the east-southeast horizon. Although separated from the Sun by just over 40° at this time, great care must be taken to avoid looking at the Sun, either with the naked eye or through widefield instruments such as binoculars. The best and safest strategy is to place the Sun behind something opaque – in other words to stand in the shadow of a building or fence so you can't see the Sun at all – leaving the area of sky to the left of the Sun in view.

Occultation of Alniyat

BEST TIME TO SEE: 10 April, start viewing from 03:00 BST (02:00 UT)

▼ A bright, 83%-lit gibbous Moon covers the star Alniyat on the morning of 10 April



Start viewing from 03:00 BST (02:00 UT) on 10 April

On the morning of 10 April, a bright 83%-lit waning gibbous Moon occults mag. +2.9 Alniyat (Sigma (σ) Scorpii). The event starts around 03:33 BST (02:33 UT) when the Moon sits 11° above the southern horizon as seen from central UK, the Moon's southwest limb hiding the star. Reappearance occurs when the Moon is due south, Alniyat reappearing from the Moon's dark southeast limb at 04:30 BST (03:30 UT). Times are given for the centre of the UK and may vary by a few minutes depending on location.

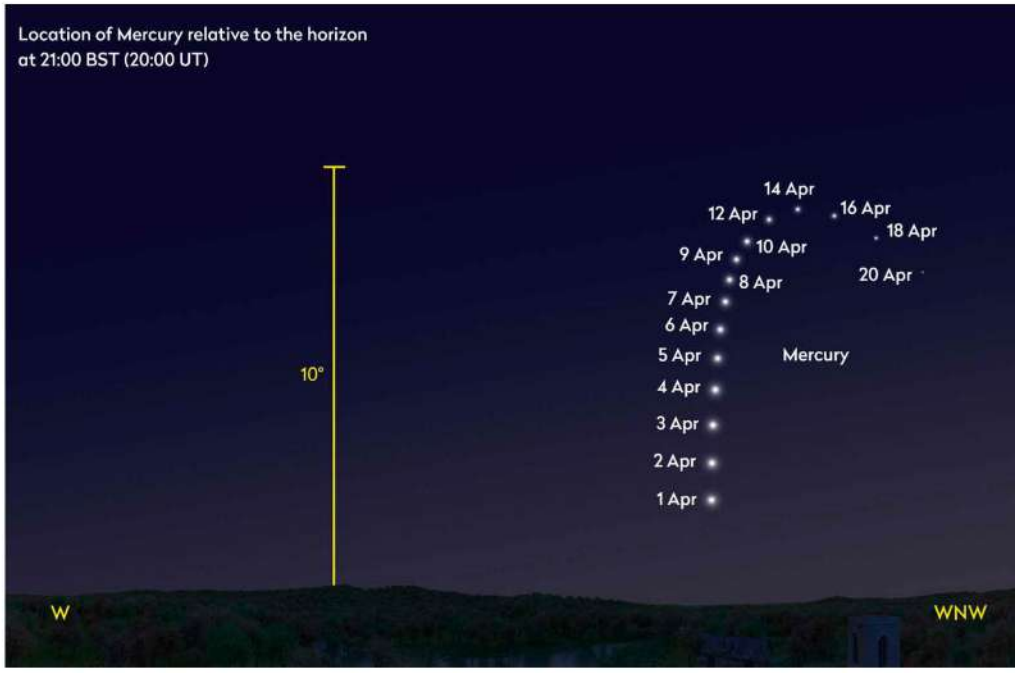
Observing lunar occultations of bright stars is rewarding. Watching the star through an eyepiece before disappearance helps you appreciate how fast the Moon's apparent motion is in the sky. A lunar occultation of a star happens quickly. Lose concentration or blink at the wrong time and the airless Moon and point source star will disappear from view in a lost instant. Reappearance is just as quick, compounded by the doubt that you may not be looking at precisely the correct part of the Moon's limb to see it.

Alniyat is one of the two stars that flank the bright-red supergiant Antares (Alpha (α) Scorpii). Shining at mag. +1.0, Antares sits 2° to the east-southeast of Alniyat.

PICK OF THE MONTH

Mercury

Best time to see: 11 April, 45 minutes after sunset
Altitude: 10°
Location: Aries
Direction: Northwest
Features: Phase, subtle surface markings
Recommended equipment: 150mm or larger



▲ **Mercury will be visible in the evening sky, appearing brightest at the start of the month**

Mercury is an evening object this month and at the beginning of April appears bright and well-separated from the Sun. This makes April a great month to try to see this elusive world. At the start of April, Mercury is reasonably bright at around mag. –1.1, but it dims rapidly thereafter. By 11 April, now shining at mag. +0.2, it reaches its greatest evening altitude at sunset. On this date, it sets a fraction over two hours after the Sun, which is great news if you're planning to look for it.

On 21 April, Mercury's dimming will have reduced it to a much trickier mag. +2.3, but it should still be possible to see it as long as you allow the evening twilight sky to darken sufficiently. A slender 3%-lit waxing crescent Moon sits 6.4° to the west of Mercury on this date. The dim planet Uranus will also be close, separated from Mercury by 3.8° but tricky to see against the twilight bright sky. Mercury thereafter closes in on the Sun fairly rapidly and will be lost from view at the end of April, with inferior conjunction occuring on 1 May.

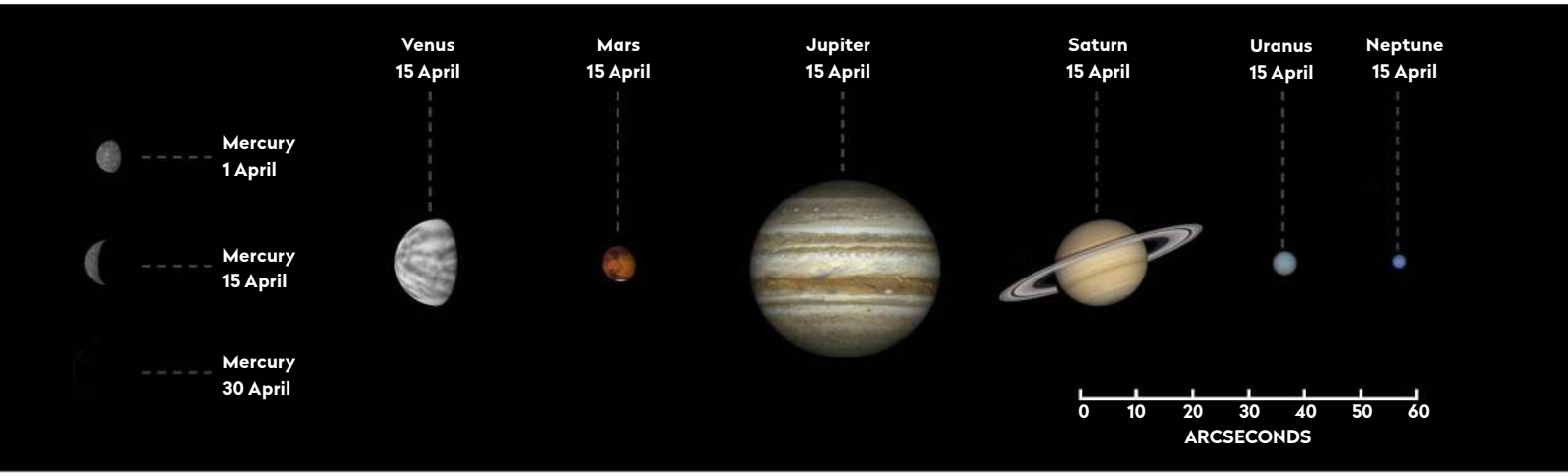
Looking at Mercury through a telescope will show the planet's phase. On 1 April, it appears tiny at 5 arcseconds across and presents a 77%-lit gibbous disc. As the month progresses, its apparent size increases in step with a decrease in phase. On 15 April, for example, Mercury now appears 8 arcseconds across and presents a phase of 26%. Trying to observe it in the evening or morning twilight will subject it to lots of atmospheric turbulence that makes seeing the planet's phase that much harder.

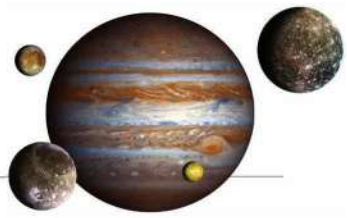
▲ **The planet's apparent size increases throughout April**

PETE LAWRENCE X 2

The planets in April

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Venus

Best time to see: 30 April, from 1 hour after sunset
Altitude: 24°
Location: Taurus
Direction: West-northwest
The magnificent evening appearance of Venus continues this month as the planet gets further from the Sun, heading towards greatest eastern elongation, its greatest separation from the Sun, on 4 June. On 10 April, mag. –3.9 Venus is just 2.7° south of the beautiful Pleiades open cluster. The sky gets astronomically dark around 22:00 BST (21:00 UT) when the pair are around 16° above the west-northwest horizon. This means there's a good opportunity for a stunning photograph.

The rapidly expanding spring evening twilight takes some of the shine off Venus during the latter part of April, but as the mag. –4.0 planet passes through Taurus at the end of the month, it is joined by a gloriously thin waxing crescent Moon on the evenings of 22 and 23 April. On 30 April, 3° south of Elnath (Beta (β) Tauri), Venus sets 4 hours and 15 minutes after the Sun. Through the eyepiece of a telescope, Venus appears 66%-lit and 16 arcminutes across at the end of April.

Mars

Best time to see: 1 April, from 21:45 BST (20:45 UT)
Altitude: 47°
Location: Gemini
Direction: West-southwest
Shining at mag. +1.0, Mars is an evening planet, and a shadow of how it appeared around opposition at the end of 2022 and the start of 2023. Through the eyepiece of a telescope, it appears 11 arcseconds smaller than it did at its peak apparent size at the start of December 2022 – it is now just 6 arcseconds across. This means that it is tricky to see much in the way of detail. On the evening of 14 April, now at mag. +1.2, the planet sits just 9 arcminutes from mag. +3.0 Mebsuta (Epsilon (ε) Geminorum). At the end of April, Mars remains in Gemini, shining at mag. +1.3 and appearing 5 arcseconds across through the eyepiece.

Jupiter

Not visible this month
Jupiter is in conjunction with the Sun on 11 April and won't be visible all month.

Saturn

Not visible this month
Saturn is poorly placed in the morning sky and unlikely to be seen this month.

Uranus

Best time to see: 1 April, from 21:30 BST (20:30 UT)
Altitude: 13°
Location: Aries
Direction: West
Uranus is too low to observe properly as astronomical darkness falls. On 1 April, the planet is just 11° above the western horizon as true darkness arrives, but after the first week in April, Uranus is almost at the horizon by the time the sky is properly dark. The planet is located 4° from mag. +1.8 Mercury on the evening of 19 April, the faint mag. +5.8 Uranus being a struggle to see against the bright twilight sky.

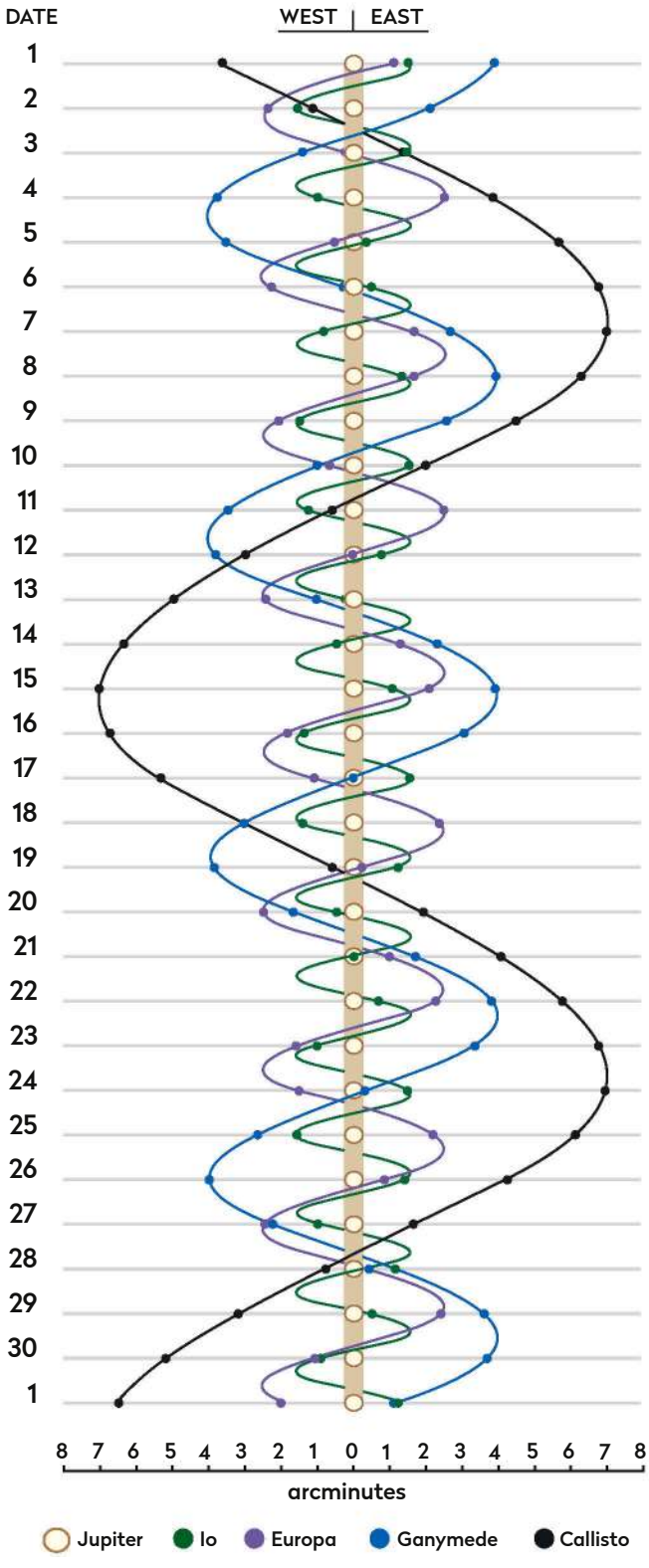
Neptune

Not visible this month
Neptune is a morning object and will be lost in the dawn twilight in April.

MORE **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: APRIL

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – APRIL

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- COMPASS AND FIELD OF VIEW
- MILKY WAY

When to use this chart

1 April at 01:00 BST
15 April at 00:00 BST
30 April at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in April*

Date	Sunrise	Sunset
1 Apr 2023	06:44 BST	19:45 BST
11 Apr 2023	06:21 BST	20:03 BST
21 Apr 2023	05:58 BST	20:21 BST
1 May 2023	05:36 BST	20:39 BST

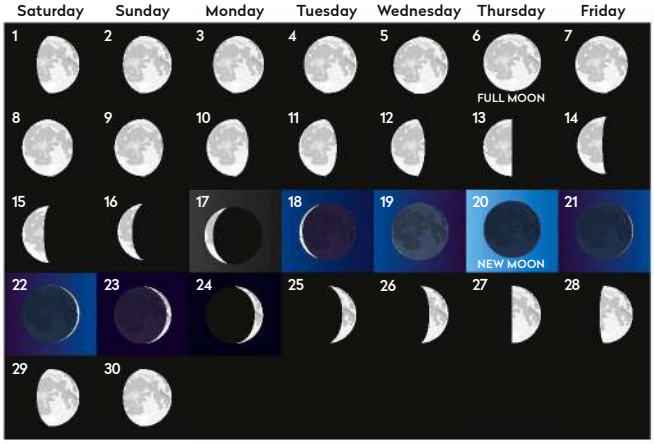
Moonrise in April*

Moonrise times

1 Apr 2023, 14:08 BST	17 Apr 2023, 05:38 BST
5 Apr 2023, 19:10 BST	21 Apr 2023, 06:23 BST
9 Apr 2023, --:-- BST	25 Apr 2023, 08:25 BST
13 Apr 2023, 04:10 BST	29 Apr 2023, 13:05 BST

*Times correct for the centre of the UK

Lunar phases in April



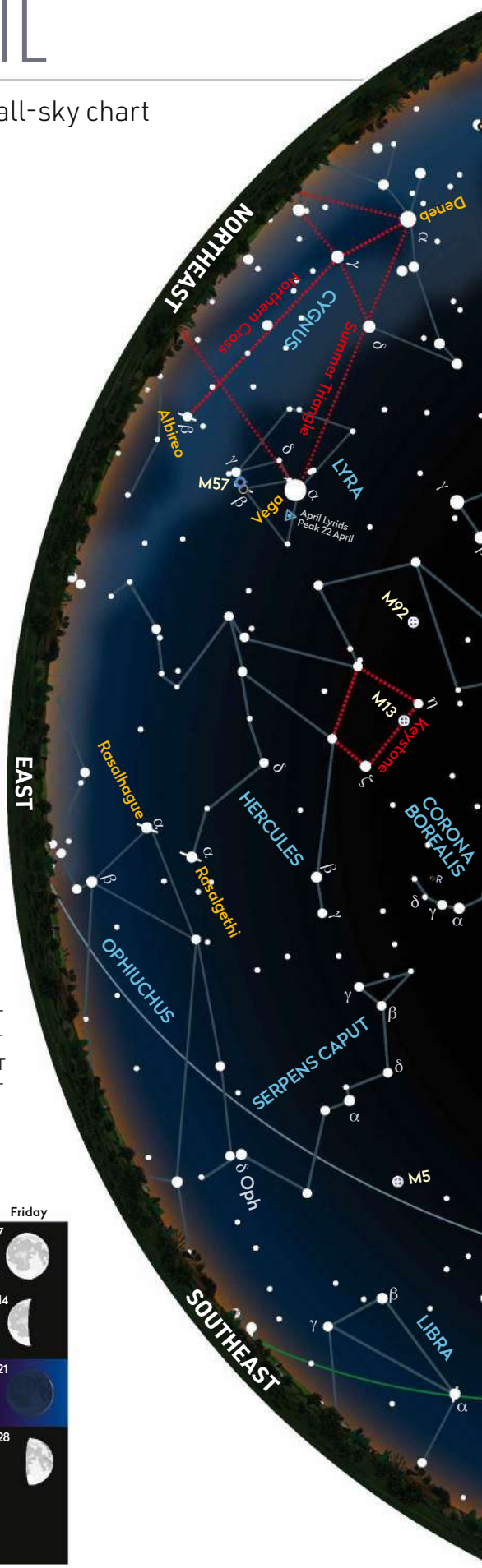


CHART: PETE LAWRENCE

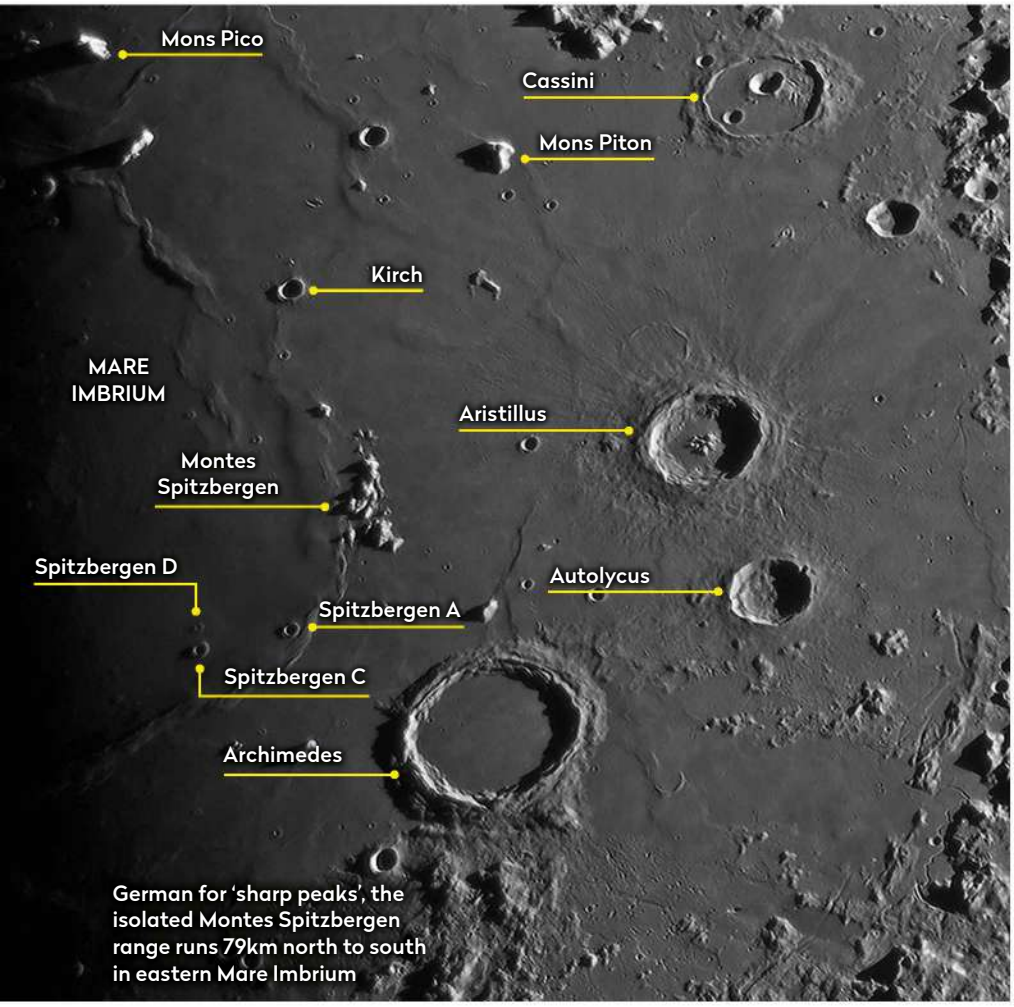
MORE **ONLINE**

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

MOONWATCH

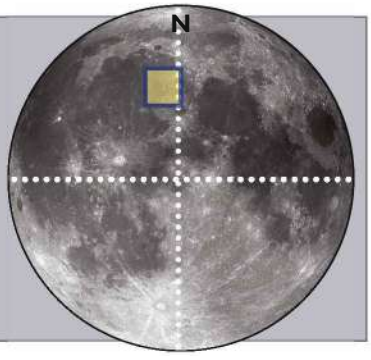
April's top lunar feature to observe



German for 'sharp peaks', the isolated Montes Spitzbergen range runs 79km north to south in eastern Mare Imbrium

Montes Spitzbergen

Type: Mountain range
Size: 79 x 24km
Longitude/latitude: 5.2° W, 34.5° N
Age: 3.2–3.9 billion years
Best time to see: First quarter (29 & 30 March, 28 April) or six days after full Moon (13 April)
Minimum equipment: 100mm refractor



Montes Spitzbergen is an impressive, solitary mountain chain located in the eastern region of **Mare Imbrium**, 150km north of the centre of the flooded 83km crater **Archimedes**. Surrounded by the 'flat' lava of Mare Imbrium, the range appears dramatic, especially when the Sun is low in its sky. Montes Spitzbergen was named for its resemblance to the largest island in the Arctic's Svalbard archipelago. The name is German for 'sharp peaks'.

Despite their impressive appearance, the mountain peaks rise to a fairly gentle height of 1.4km above the surrounding lava plains. The range measures 24km east to west at its widest point, and stretches for 79km north to south. The mountains in the range are not continuously joined, interrupted by lava at a location slightly south of the mid-point. Two isolated mountains appear east and west of the gap. While looking in the region, head south towards Archimedes where you'll find a couple of additional isolated mountain massifs. Similarly, head north from the main range, first past a trio of low-level isolated peaks, then on to a more rectilinear mountain, again on its own against the Imbrium surface.

As with any relief feature, the real fun begins when the Sun gets low. When high, near full Moon, Montes Spitzbergen appears bright against the darker lava of Mare Imbrium. However, when the Sun's altitude drops, the individual mountains start to cast shadows. As the material surrounding the range is relatively flat – we'll come on to that in a moment – the lengthening shadows to the east when the Sun is setting or west when it's rising, look particularly dramatic. At times when the Sun is really low from Montes Spitzbergen, as is the case when the terminator is nearby, shadows become particularly exaggerated, jagged and sharp. This can give a false impression of height.

The floor of Mare Imbrium looks quite flat when the Sun is high in the mare's sky. But when it's low, lumps and bumps become very evident. A number of impressive wrinkle ridges can be seen in the vicinity, Montes Spitzbergen appearing to cross one that arcs north to south and then west, located further to the west of the range. A wrinkle ridge is a tectonic feature that forms after a large area of lava cools and solidifies.

A small group of three craters lies to the southwest of Montes Spitzbergen. The eastmost one is 7km **Spitzbergen A**, similarly sized **Spitzbergen C** located 45km further to the west. The tiny 3km craterlet 13km north of Spitzbergen C is **Spitzbergen D**, a good test for a 200mm instrument under steady seeing.

When the Sun is really low, the shadows become jagged and sharp

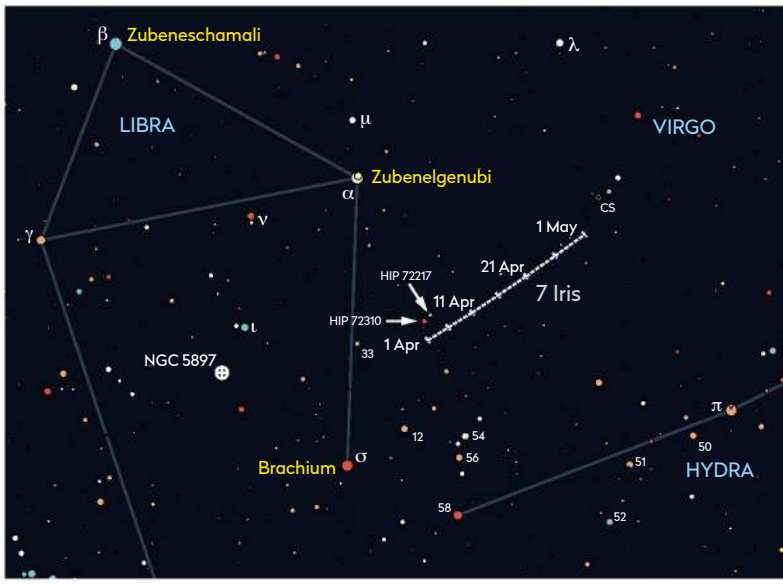
There is plenty of impressive lunar real estate in the immediate vicinity too, the stand-out feature being 83km **Archimedes** to the south. 154km to the east is 55km **Aristillus** which has a superbly detailed central mountain complex. Look out for the unnamed ghost crater located immediately to the north of Aristillus. Further south is 40km **Autolycus**.

COMETS AND ASTEROIDS

UK observers with telescopes will be able to view minor planet 7 Iris all month

Minor planet 7 Iris reaches opposition on 30 April, when it will be well-placed within the constellation of Libra, approximately three-fifths of the way along a line from Spica (Alpha (α) Virginis) towards Zubenelgenubi (Alpha (α) Librae). From the UK, this location gets to an altitude of around 22°, not particularly high, but still enough to give a reasonably clear view. Iris begins the month just south of a pair of sixth-magnitude stars found by first identifying the mid-point between Zubenelgenubi and Brachium (Sigma (σ) Librae), then extending a line at right angles to the line between both stars from this point for 2.4° westward. The stars are easy to locate with binoculars. At mag. +10.1, Iris will be too faint to see through average binoculars throughout the month, a small telescope being the minimum equipment needed.

At 00:00 BST (01:00 UT) on 1 April, shining at mag. +10.2, Iris sits half a degree below the star pair mentioned (HIP 72217 and HIP 72310). It then tracks west-northwest, passing through a fairly barren star-scape, north of Hydra's tail stars. It passes a fraction south of mag. +6.6 HIP 70518 on 28 April. On opposition date, 30 April, Iris brightens to mag. +9.6 and is located adjacent to Libra's western border with Virgo. Again, the lack of bright field stars in this part of the sky will make observing this minor planet an interesting spring challenge.



▲ 7 Iris will be faint, with a mean opposition magnitude of just +7.8

Discovered by the English astronomer John Russell Hind on 13 August 1847, Iris is an S-type (siliceous, stoney) asteroid with a mean diameter of 241 kilometres. It orbits the Sun between Mars and Jupiter (in the main asteroid belt) varying its distance from the Sun between 1.83 AU and 2.94 AU. It takes 3.7 years to complete each orbit.

STAR OF THE MONTH

Vindemiatrix, the lip of the Bowl of Virgo

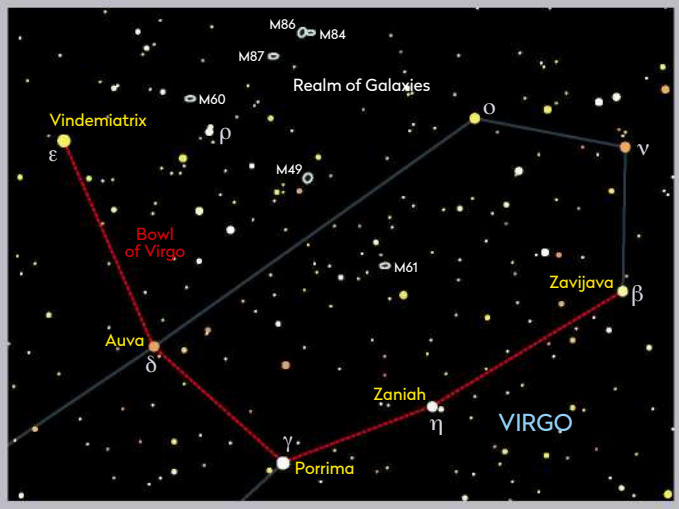
Vindemiatrix is the third-brightest star in Virgo, shining at mag. +2.8. Located 110 lightyears away, it marks the eastern lip of the large semi-circular pattern known as the 'Bowl of Virgo'. Measuring 20° across, the bowl is formed from Vindemiatrix, Auva, Porrima, Zaniah and Zavijava, Epsilon (ε), Delta (δ), Gamma (γ), Eta (η) and Beta (β) Virginis respectively. The bowl stars are collectively part of Al 'Awwā', which is Arabic for 'the Barker'.

The name Vindemiatrix originates from the Greek term for 'the grape gatherer', somewhat corrupted in its Latinised form to mean 'the grape harvestress'. First morning visibility was a sign it was time to pick the grapes.

Vindemiatrix is a G8 III star: a yellow (G8), giant (III) star with a photospheric temperature of 5086K. It's 2.6 times more massive than the Sun and 77 times more luminous. Interestingly, it's a bright X-ray source, estimated to be 300x brighter than the Sun in this part of the spectrum. The strong X-ray output is presumably due to its strong magnetic field affecting the star's surface. The star's spectrum has been used as a reference for the classification of other stars since 1948.

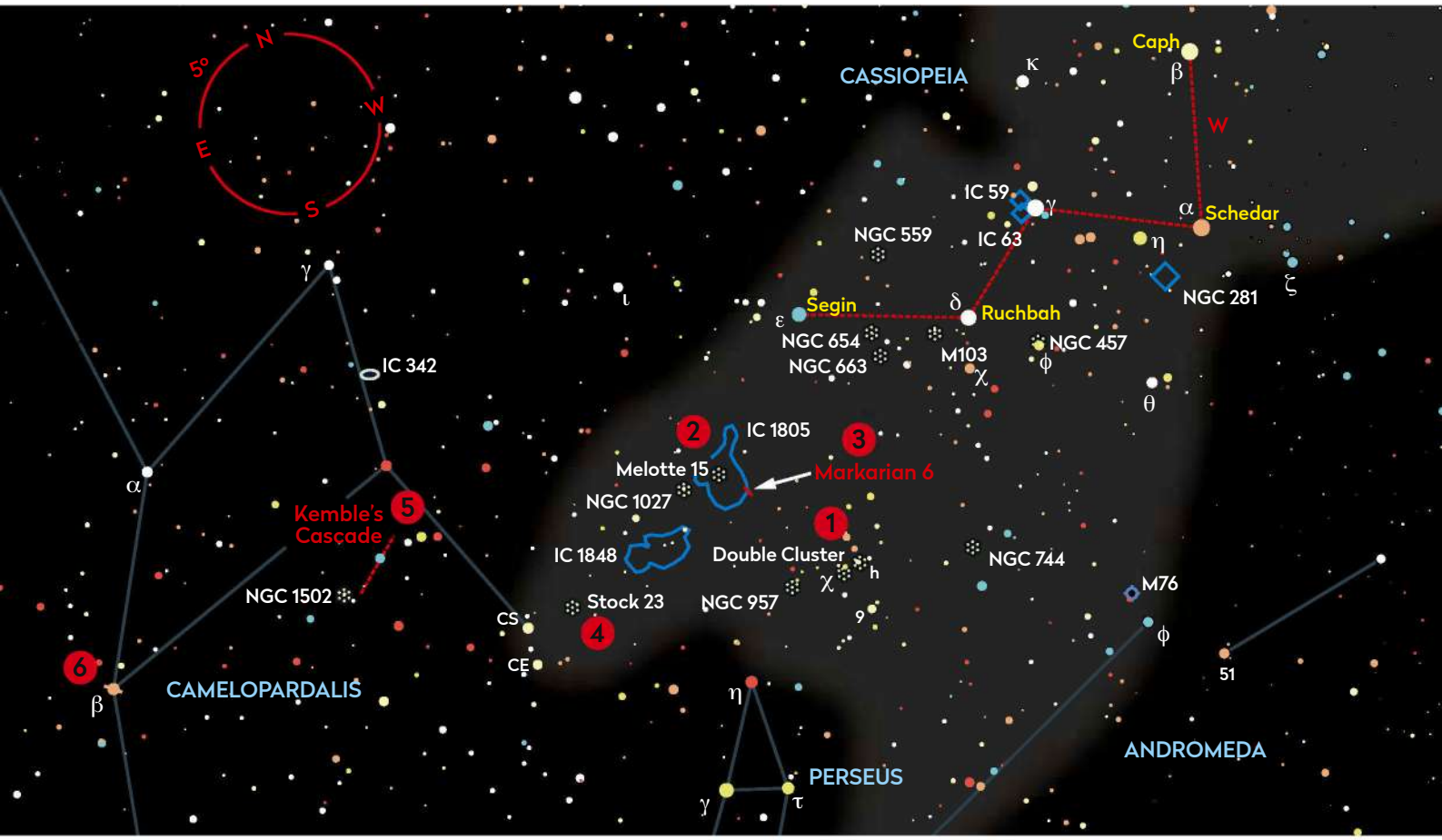
Estimated to be around 560 million years old, Vindemiatrix is thought to have started life as a white B-class star and to now have a core that's in the process of switching from hydrogen to helium fusion. It rotates fairly slowly at 2.3km per second, taking 173 days to complete one rotation.

▼ Vindemiatrix leads the five stars of the Bowl of Virgo, a large semi-circular asterism visible in spring



BINOCULAR TOUR With Steve Tonkin

This month's targets include a double act, a cascade and the heart of the Heart



1. The Double Cluster

10x50 Half way between mag. 2.6 Ruchbah (Delta (δ) Cassiopeiae) and mag. +2.9 Gamma (γ) Cassiopeiae you will find a close pair of open clusters. In a rural sky, you can see them with your naked eye as a distinctly elongated smudge of light, but binoculars will reveal two little concentrations of stars. Those stars are intrinsically extremely bright: if the Sun was there, it would be too faint for you to see it in binoculars! ☐ **SEEN IT**

2. Melotte 15

10x50 If you imagine that mag. +3.3 Segin (Epsilon (ε) Cassiopeiae) and mag. +4.6 Iota (ι) Cassiopeiae are two corners of an equilateral triangle, Melotte 15 is the third corner. In 10x50 binoculars, you'll see a large (20-arcminute) glow with a handful of brighter stars forming a V shape. If you have a UHC filter to hold over an eyepiece, you might see the nebulosity (IC1805, the Heart Nebula) that surrounds, and gave birth to, the cluster. ☐ **SEEN IT**

3. Markarian 6

15x70 Markarian 6 lies slightly less than 1° to the south-southwest of Mel 15. It's quite easy to miss, so we use larger binoculars. What you should see is an arrow of half a dozen ninth-magnitude stars pointing southwards. Owing to its faintness compared to Mel 15, you might assume it is much further away, but at 1,600 lightyears it is actually just under a quarter of the distance. ☐ **SEEN IT**

4. Pazmino's Cluster

10x50 If you pan slightly more than 1.5° due west from mag. +4.3 CS Camelopardalis, you will find an unremarkable little trapezium of seventh and eigth-magnitude stars. This is Stock 23, also known as Pazmino's Cluster. Your binoculars should reveal that this is much more than a trapezium and you may be able to resolve about half a dozen stars against a faintly glowing patch of sky about 10 arcminutes in diameter. ☐ **SEEN IT**

5. Kemble's Cascade

10x50 On spring evenings, Kemble's Cascade is near-horizontal in the sky, so this line of eighth-magnitude stars, with a brighter fifth-magnitude one in the middle, looks more like a wristwatch or bracelet opened out against the sky than a tumbling cascade. To find it, extend a line from mag. +2.3 Caph (Beta (β) Cassiopeiae) to Segin the same distance to the central bright star. ☐ **SEEN IT**

6. Beta Cam

10x50 You can see mag. +4.0 Beta (β) Camelopardalis with the naked eye, and its mag. +7.4 companion, which lies 84 arcseconds southwest is easy to distinguish, even in small binoculars. Beta Cam is a yellow supergiant in transition between being a hot new blue star and a much cooler red supergiant. It sometimes flashes, probably due to the equivalent of huge solar flares. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Visually demonstrate the two types of solar time with this year-long project

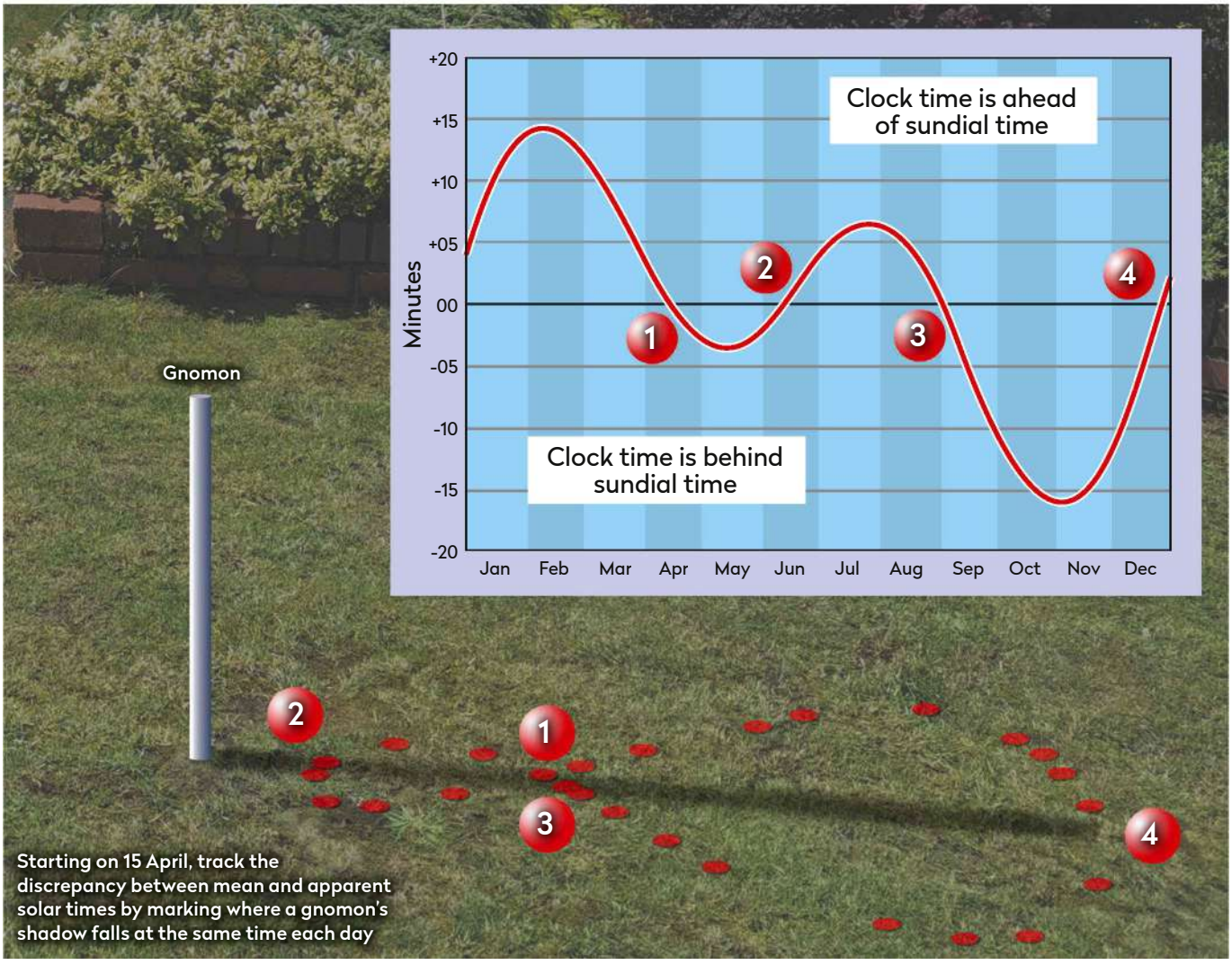
A sundial is an easy way to measure time. You simply put a stick in the ground and mark where the end of the stick's shadow falls on the hour. Not too much of a challenge you might think, but there are hidden details you need to consider.

The trouble is, the sundial's measured daily time starts to drift with respect to clock time. Time will not always be shown accurately, a small difference at first, then larger, then smaller, then zero and so on. The problem isn't with your sundial, it's with the Sun, or rather with Earth. Earth's orbit about the Sun isn't a circle, it's an ellipse. As we travel around the Sun, the elliptical orbit causes the Earth–Sun distance and our orbital speed to alter. For us sitting on the surface of our planet, the apparent speed of the Sun across the sky appears to speed up and slow down in a periodic manner. We can't gauge time properly using this variable Sun, known as the real or apparent Sun, so we create an imaginary one which moves across the sky at a consistent rate: the mean Sun.

The mean and apparent Sun align on four dates throughout the year: this month on 15 April, then 13 June, 1 September and 25 December (correct for J2000.0). At such times, the end of the shadow of our sundial stick (gnomon) marks the correct time. On other days the mean Sun is either ahead of or behind the apparent Sun. The difference is known by the rather enigmatic name of 'the equation of time' and can range from 14 minutes and 15 seconds ahead of clock time to 16 minutes and 25 seconds behind.

The variation can be demonstrated to great effect by photographing the position of the Sun over the course of a year at the same UT time. If you do this, the equation of time causes it to oscillate back and forth. However, Earth's axial tilt also plays a part, causing the Sun to appear to move up and down in the sky over the course of a year. As a consequence, the equation of time plus declination drift produces a bowling pin shape in the sky, known as an analemic curve.

Marking the position of a gnomon's shadow tip at the same time of day throughout the year will also produce this curve, and that's your challenge for the rest of 2023 and into 2024! This requires good placement of the gnomon so it'll be in Sun throughout the year. It also requires good weather. Don't worry about missing days though – the shape can still be revealed, even with many gaps.

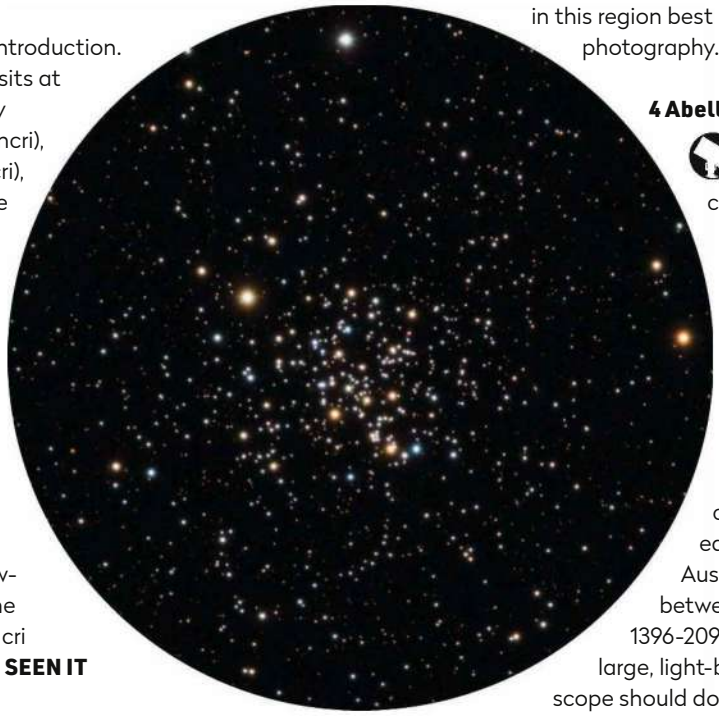


DEEP-SKY TOUR

Our tour includes peculiar galaxies and ancient clusters in the middle of Cancer

1 M44

Our first target needs no introduction. M44, the Beehive Cluster, sits at the heart of Cancer, boxed in by Asellus Borealis (Gamma (γ) Cancri), Asellus Australis (Delta (δ) Cancri), Eta (η) and Theta (θ) Cancri. The cluster is rich, large and visible to the naked eye under dark skies. With an estimated distance of 594 lightyears, it's one of the nearest open clusters, appearing 95 arcminutes across. It contains over 200 members, 20 brighter than mag. +8. M44 contains many multiple stars and in excess of 100 variables. Most appear towards the yellow-red end of the spectrum, but one stand-out variable star, TX Cancri (mag. +7 to +8) appears blue. ☐ **SEEN IT**



▲ Smaller and dimmer than the more famous M44, M67, one of the oldest open clusters in the Milky Way, contains as many as 100 Sun-like stars

2 NGC 2672

Next is the elliptical galaxy NGC 2672. Wander to the southernmost edge of M44 (near TX Cancri) and look 1.9° to the east. The galaxy lies 0.4° northwest of mag. +6.4 HIP 43427. Discovered on 14 March 1784 by William Herschel, NGC 2672 is just about visible with a 150mm scope under dark skies, but relatively easy to see using a 250mm instrument. It appears circular around 40 arcminutes across, a glow with a tiny, almost stellar nucleus. There's a challenge here for larger instruments: seemingly embedded within the east-southeast portion of NGC 2672's outer halo is galaxy NGC 2673. In terms of brightness, NGC 2672 has an integrated magnitude of +11.6 and NGC 2673 is +12.9. ☐ **SEEN IT**

3 NGC 2749

Another elliptical galaxy, mag. +12.0 NGC 2749 is located 3.5° east of HIP 43427 mentioned above. It's also 3.9° south and a fraction west of mag. +5.2 Xi (ξ) Cancri (not shown). This is a tricky object requiring aperture to see. A 250mm scope shows it as a glow about 1 arcminute in diameter. The glow appears mostly uniform, but rising to a sharp star-like nucleus. A 300mm scope shows a similar view except the nucleus appears displaced slightly towards the northeast. This is the brightest of a group of galaxies in this region best revealed using long-exposure photography. ☐ **SEEN IT**

4 Abell 30

The Abell Catalogue of Planetary Nebulae was compiled in 1966 by George Abell. It consists of 86 largely faint objects, most discovered on photographic survey plates taken with a 1.2m telescope at Mount Palomar. Shining at integrated mag. +13.0 and with a total apparent diameter of 2.1 arcminutes, Abell 30 is a very challenging object. It lies 0.6° east-southeast of Asellus Australis, roughly mid-way between this star and mag. +8.4 TYC 1396-2099-1. This is best-suited to a large, light-bucket instrument. A 450mm scope should do it, showing a 0.5-arcminute circular glow and dim mag. +14.3 central star. An OIII filter is helpful visually. If you don't have a large scope, photography is the way to go. ☐ **SEEN IT**

5 NGC 2648

NGC 2648 lies approximately two-thirds of the way from mag. +4.3 Acubens (Alpha (α) Cancri) and mag. +6.3 HIP 42187. It has an apparent magnitude of +11.8, but with a total apparent size of 3.2 x 1.1 arcminutes has low surface brightness. Only the bright core, about 50 arcseconds long, appears visually. The Palomar Sky Survey plates mentioned above were also used to identify many members of the Arp Atlas of Peculiar Galaxies, galaxies with unusual structures typically generated from active nuclei or gravitational distortions. Many are difficult targets for amateurs. Together with the adjacent mag. +14.6 galaxy PGC 24469, NGC 2648 forms Arp 89. ☐ **SEEN IT**

6 M67

Overshadowed by its larger and brighter Messier neighbour, M67 is a sixth-magnitude open cluster 2° west of Acubens (Alpha (α) Cancri). With an apparent diameter around 30 arcminutes, through the eyepiece of a telescope M67 appears rich and condensed. A 150mm instrument reveals around 50 stars brighter than mag. +12 in an area 0.25° across. Around 100 members are visible in a 300mm scope at 120x power. The brightest star in the cluster appears to be HIP 43519 which shines at mag. +7.8, although this is a foreground object estimated to be one-quarter the 2,700-lightyear distance of M67. ☐ **SEEN IT**

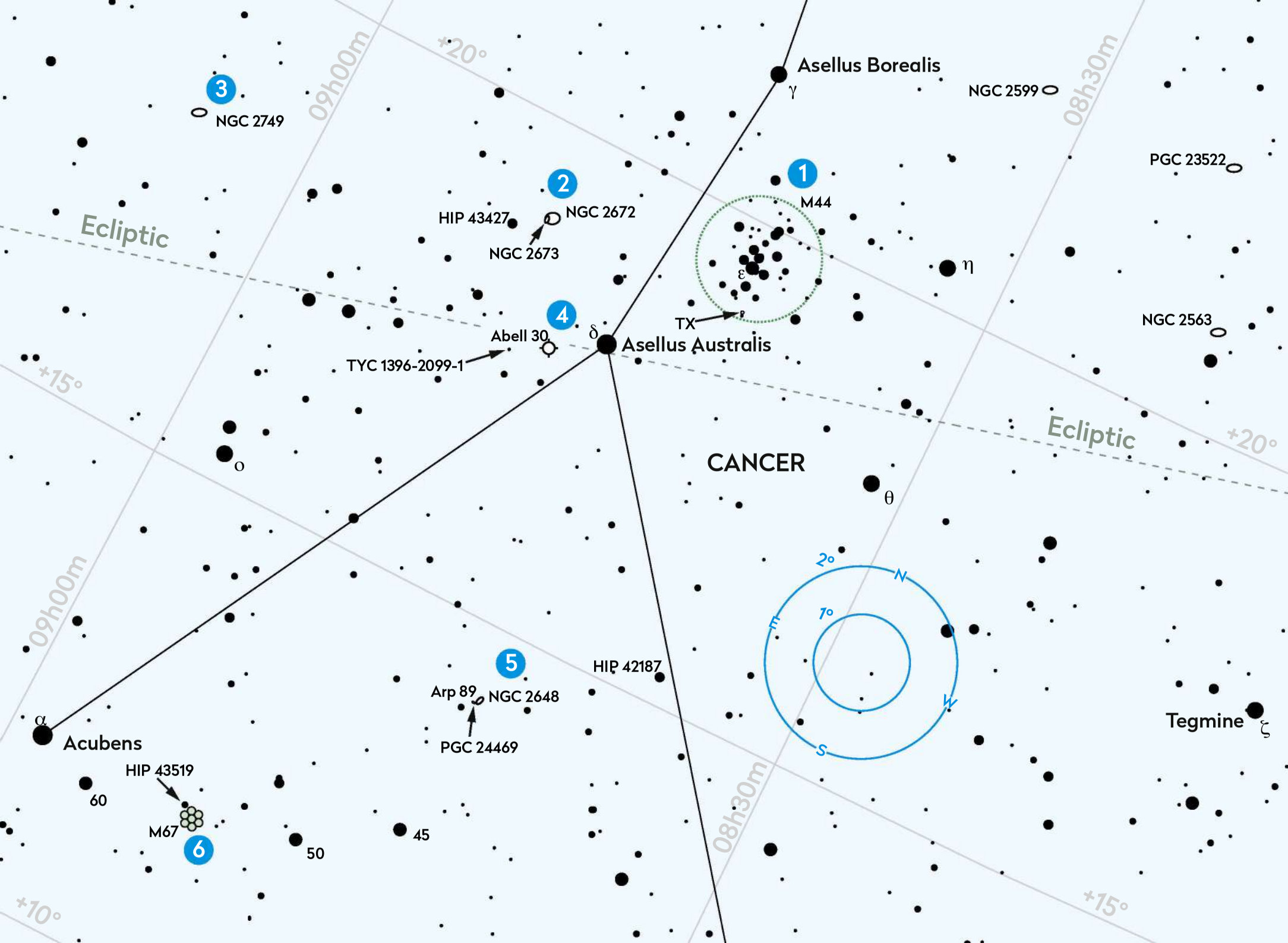
BERNHARD HUBL/CCDGUIDE.COM, CHART BY PETE LAWRENCE

This Deep-Sky Tour has been automated

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions


3
NGC 2749
09h00m
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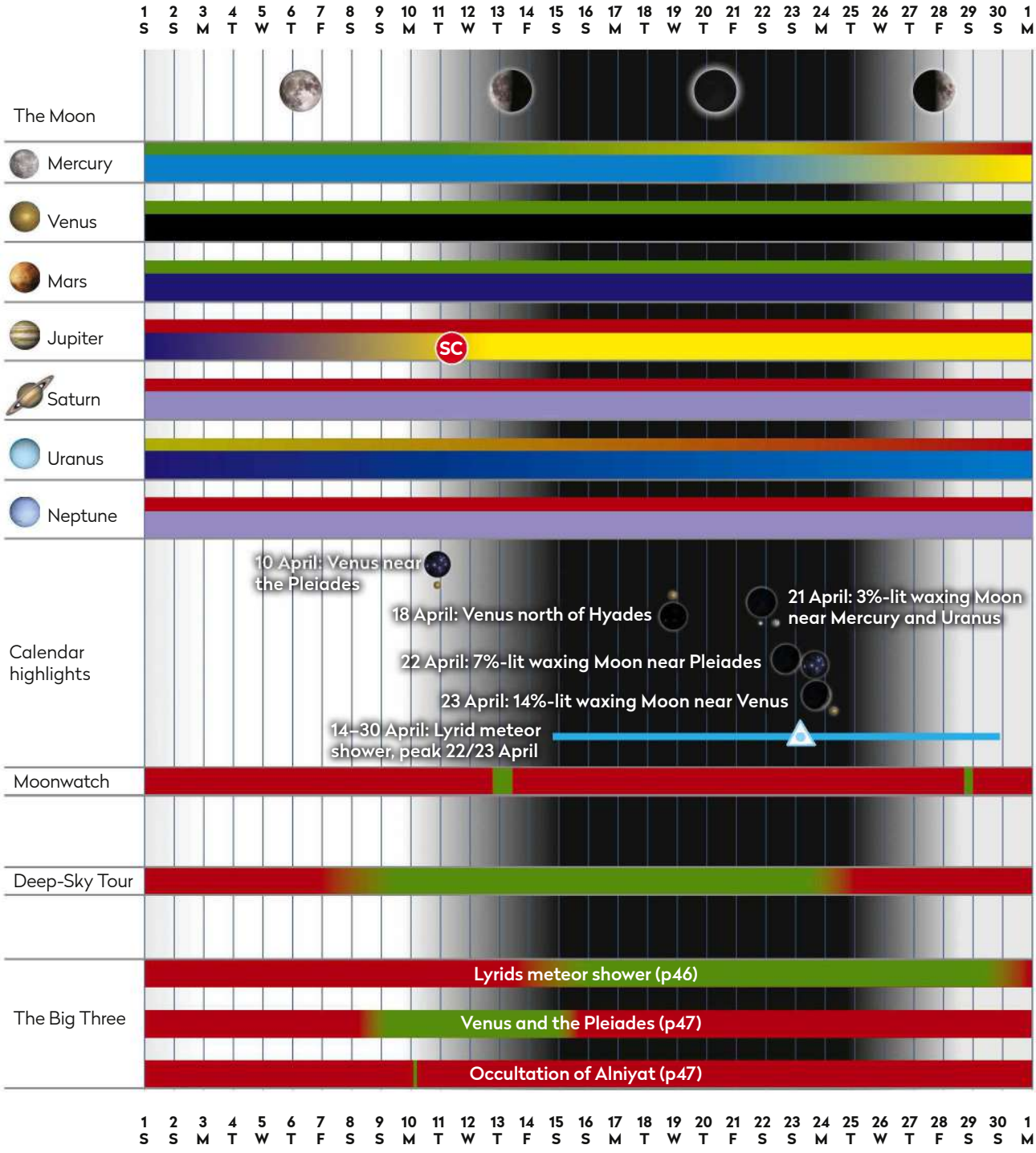
AT A GLANCE

How the Sky Guide events will appear in April


1 S 2 S 3 M 4 T 5 W 6 T 7 F 8 S 9 S 10 M 11 T 12 W 13 T 14 F 15 S 16 S 17 M 18 T 19 W 20 T 21 F 22 S 23 S 24 M 25 T 26 W 27 T 28 F 29 S 30 S 1 M
The Moon
Mercury
Venus
Mars
Jupiter
SC
Saturn
Uranus
Neptune
Calendar highlights
10 April: Venus near the Pleiades
18 April: Venus north of Hyades
21 April: 3%-lit waxing Moon near Mercury and Uranus
22 April: 7%-lit waxing Moon near Pleiades
23 April: 14%-lit waxing Moon near Venus
14–30 April: Lyrid meteor shower, peak 22/23 April
Moonwatch
Deep-Sky Tour
The Big Three
Lyrids meteor shower (p46)
Venus and the Pleiades (p47)
Occultation of Alniyat (p47)
1 S 2 S 3 M 4 T 5 W 6 T 7 F 8 S 9 S 10 M 11 T 12 W 13 T 14 F 15 S 16 S 17 M 18 T 19 W 20 T 21 F 22 S 23 S 24 M 25 T 26 W 27 T 28 F 29 S 30 S 1 M

KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

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The two-day event brought together players from across the space industry, including space agencies, private companies, legal experts and policy-makers

The new Space Age

With 70 nations, space-mad billionaires and eager private companies all vying for a stake – but no laws or rules – space today is verging on a free-for-all. **Shaoni Bhattacharya** hears discussions on the challenges at the Abu Dhabi Space Debate

© 2022 ABU DHABI SPACE DEBATE

Last summer, Ian Christensen was staring up at the night sky above a US National Park and International Dark Sky area. He and his companions were listening to a ranger talk about the wonders of the night sky when they were confronted with an unexpected sight: a train of dots crossing the Milky Way.

"For me it was a crystallisation," he told delegates at the Abu Dhabi Space Debate. "Here's a system with benefits... but also a direct and discernible impact on how we as a species engage with the environment."

Christensen – who is the director of private sector programmes at the Secure World Foundation, an organisation that aims to promote space sustainability – was one of many speakers at the two-day meeting in December 2022, organised by the United Arab Emirates. It was the first-ever international meeting solely dedicated to addressing new space challenges on a global scale. While space has been on the agenda at major world meetings before, including the COP climate meetings, it has always been as an adjunct, a side issue among many others.

Now with rising numbers of new players in space, out-of-date rules and tensions rising both on Earth and in space, the Space Debate aimed to provide a forum to cooperatively discuss the future of space. ▶

▲ Her Excellency Sarah Al Amiri, chair of the UAE Space Agency, launched the conference and led discussions on space and climate change

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▶ Safety and the sustainability of space were high on the agenda. Who owns space? Who makes the laws? Who will pay for the clean-up of space debris? These were some of the questions running through the debate.

"We have moved from the bi-polar world of the Cold War and its Space Race to a multilateral world where some 70 nations are space-capable; where a fast-growing private sector is taking an increasing role and global tensions have threatened some of the most cherished aspects of our exploration of space," said Her Excellency Sarah Al Amiri, chair of the UAE Space Agency in her opening remarks.

A problem shared

The 'new Space Age' has brought with it many issues, Al Amiri highlighted, including the growing problem of space debris and of our most important piece of existing international legislation, the Outer Space Treaty, being more than 50 years out of date.

The meeting was attended by world leaders, representatives from space agencies and private companies. At one point, Japanese astronaut Koichi Wakata provided some pazazz to proceedings by speaking online from the International Space Station to delighted delegates, flying upwards in microgravity at the end of his address to whizz off screen.

With access to space becoming easier and cheaper, there are huge opportunities to be had, such as improving broadband accessibility in underserved communities and providing Earth observation capabilities to help combat climate change. But there are also concerns. One major worry is that space is becoming increasingly congested, especially in low-Earth orbit (LEO). In recent years, this has been compounded by the rise of giant networks of thousands of satellites called

Growing anxiety about satellites

Megaconstellations impact our ability to view the cosmos around us

Human activity in low-Earth orbit is rapidly increasing. There were about 800 active satellites in LEO in 2019, according to Dan Ceperley, CEO of LeoLabs. There were about 6,000 satellites in LEO at the time of the meeting in December, but this is on track to rise to 10,000 satellites by the end of 2023.

As well as safety and sustainability issues, the number of satellites has raised concerns for astronomers and stargazers. "As these systems have been deployed, we've found that they actually optically interfere with telescope observations," said Ian Christensen of the Secure World Foundation. "They're deployed in 'trains' – 50 or 60 in a single launch – and as those satellites transit across the field of view of terrestrial telescopes, they reflect light back into the telescope and interfere with the ability to collect clean observations."

Christensen did highlight there has been constructive dialogue between the optical astronomy and satellite-operating communities. The International Astronomical Union has established a Centre for the Protection of the Dark and Quiet Skies, with four working groups focusing on different issues, including working with industry to design practices for satellite constellations that might reduce the amount of interference and contamination of images.

A train of satellites from the Starlink megaconstellation streaks across the sky in March 2020

Hopefully, these measures would also reduce the visibility of these systems to the general public too, protecting it not just for stargazers, but the many cultures and religions around the world that have a deep connection to the night sky.

▲ Japanese astronaut Koichi Wakata spoke to delegates from aboard the ISS

megaconstellations. Of the 6,000 satellites in orbit, half are part of the Starlink network, and another 9,000 are planned. There are even some reports that the company has requested authorisation to launch up to 42,000. The number is only set to grow as other private space companies around the world prepare to launch their own constellations over the next few years. It's becoming increasingly clear that LEO is a finite resource.

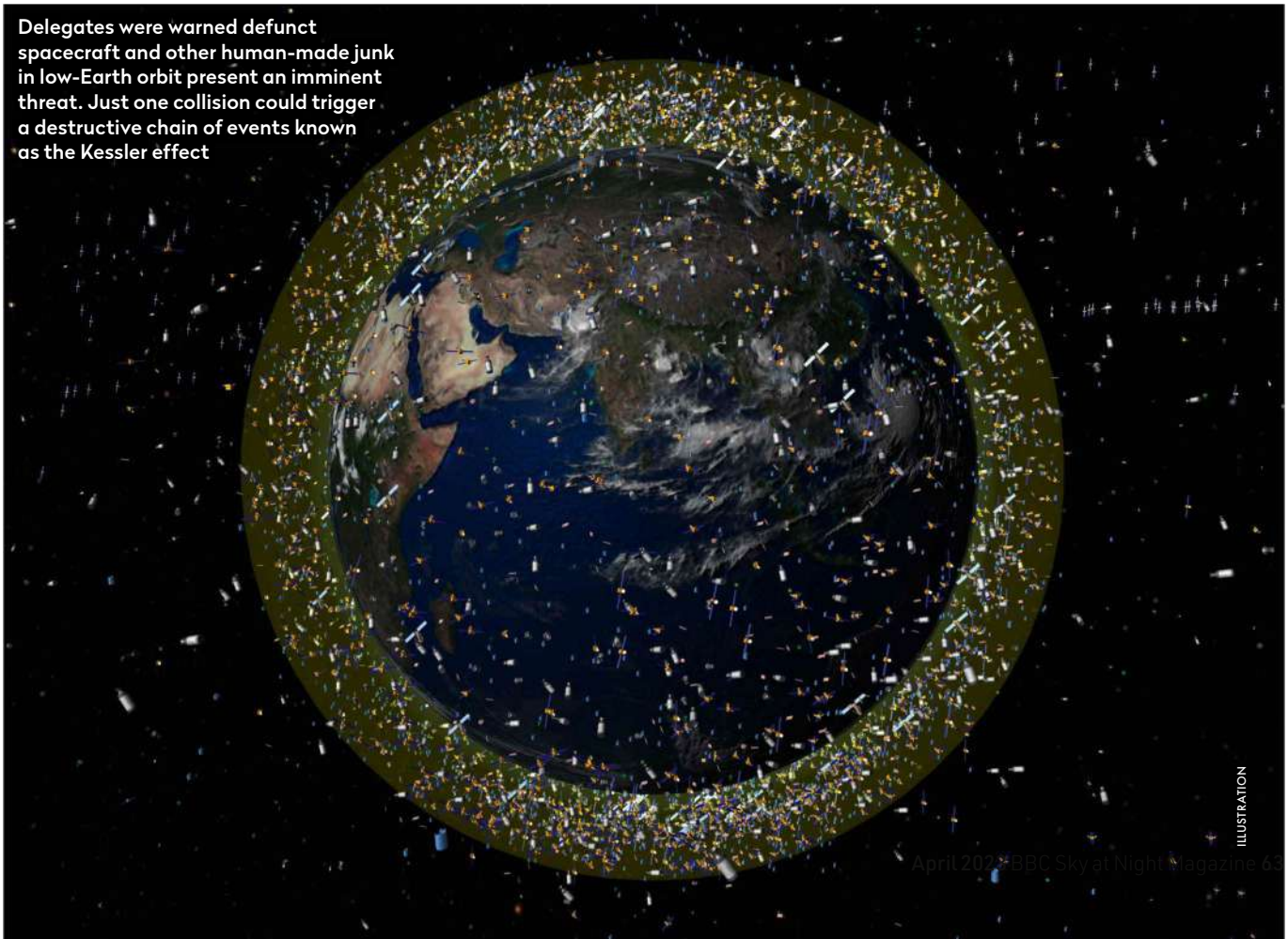
"While some may look at the possibility of endless exploitation as perhaps our ancestors looked at the oceans, we know that there are limits," said Adnan Al Muhairi, chief technology officer of satellite company Yahsat. "We have over 250 new companies that have made announcements for constellations. Some are looking at tens of thousands [of satellites]. Not to mention the potential entry of over 100 new launch vehicle manufacturers as well."

Debris dilemma

With so many new entrants, safety and sustainability are a concern to both public and private sectors. The increasing use of LEO has implications for radio astronomy and stargazing due to the light pollution caused by these satellites, but they are also a threat to humanity's continued use of space and the many advantages that it brings, due to increased space junk. A fragment of a spacecraft as small as 3cm could cause catastrophic damage to another spacecraft should they strike each other, and there are already thousands of pieces of debris.

Meanwhile, the private sector is well aware that sustainability in space is integral to its business. "For us to survive as companies, we have to create a sustainable space future," said Erika Wagner from spaceflight company Blue Origin.

"It's on our shoulders to make sure this is safely operated, safely regulated," says Laith Hamad, from ▶



Delegates were warned defunct spacecraft and other human-made junk in low-Earth orbit present an imminent threat. Just one collision could trigger a destructive chain of events known as the Kessler effect

ILLUSTRATION

▶ communications company OneWeb. "If you have one collision – only one collision – and you start the Kessler effect, then space is of no use to us."

The Kessler effect or Kessler syndrome is a situation theorised by NASA scientist Donald Kessler in 1978 where the density of satellites, spent rockets and other space junk becomes so high that it reaches a critical mass and just one collision could trigger a runaway cascade. Each collision creates more debris, which increases the chances of a collision, creating even more debris and so on, until orbit becomes unusable.

Hooked on space

Many made comparisons between humanity's unsustainable use of Earth and what our species is currently doing in space. Carrying on with a 'business as usual approach' could run a real risk of space becoming unsustainable, warned Steven Freeland, vice-chair of a UN working group on Legal Aspects of Space Resource Activities.

"We are all dependent on space for all aspects of our lives – it's part of the critical infrastructure," said Freeland. "It could put us all back into the Dark Ages."

If LEO does veer into such a path, the results could be irreversible. While technology such as using lasers or nets to actively remove space debris, or space tracking might offer potential solutions, it isn't enough.

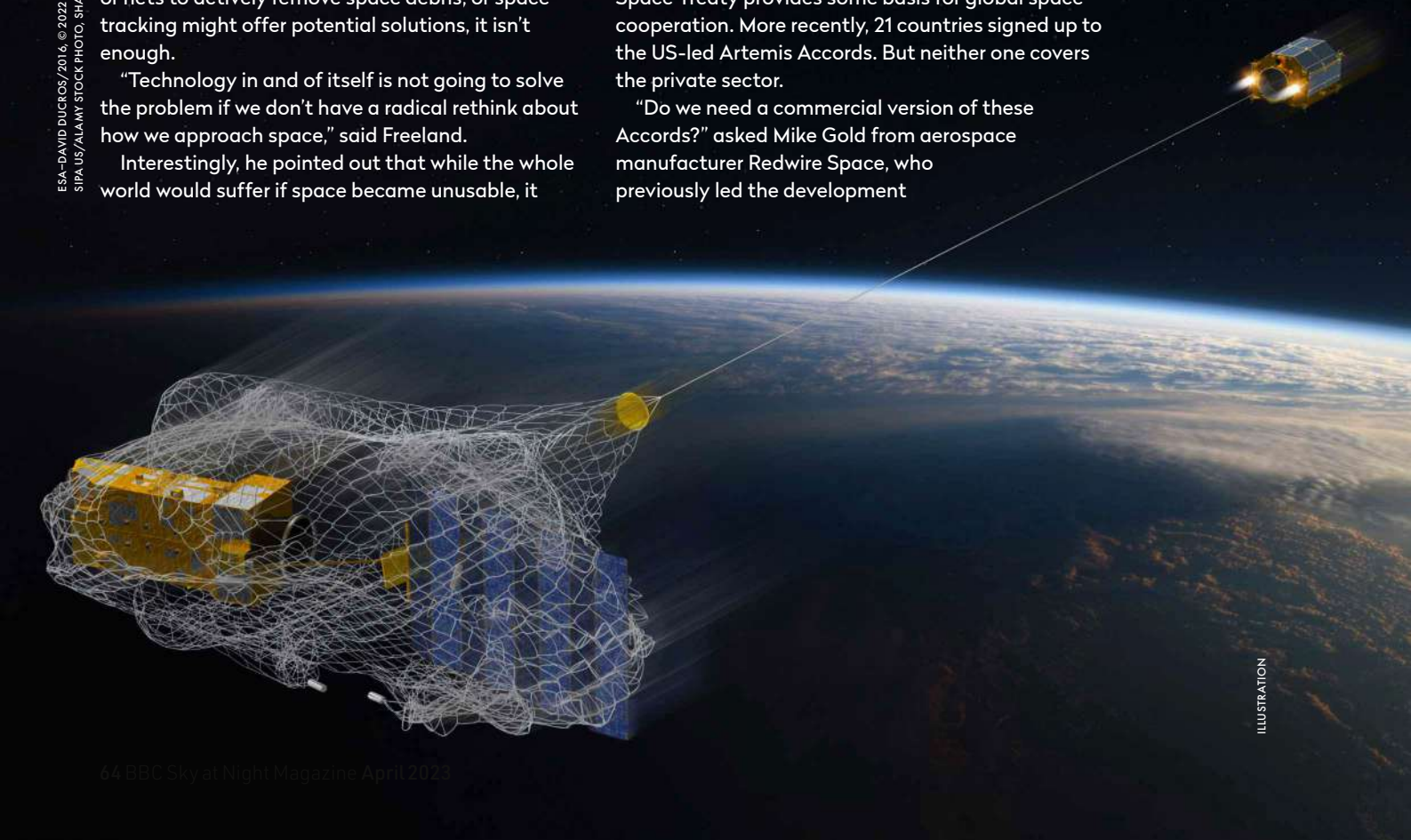
"Technology in and of itself is not going to solve the problem if we don't have a radical rethink about how we approach space," said Freeland.

Interestingly, he pointed out that while the whole world would suffer if space became unusable, it would be the richer, more powerful countries that would suffer the most – a stark contrast to the situation with climate change on Earth. This is because the largest spacefaring nations are also the most dependent on the incredible advantages space offers, and therefore the most vulnerable. This common interest would be a powerful tool to promote changes to the way the world adapts to and uses space.

"Technology in and of itself is not going to solve the problem if we don't have a radical rethink about how we approach space" – Steven Freeland

One of the biggest problems, however, is that space is shared between all humanity. There is currently no universal set of rules or agreements that cover all spacefaring nations and the private sector. Nor is there an overarching regulatory or enforcement body, as noted during the debate, making space potentially a free-for-all. The Outer Space Treaty provides some basis for global space cooperation. More recently, 21 countries signed up to the US-led Artemis Accords. But neither one covers the private sector.

"Do we need a commercial version of these Accords?" asked Mike Gold from aerospace manufacturer Redwire Space, who previously led the development



▼ Mechanical nets that snare space junk are one idea mooted to tackle the congestion in low-Earth orbit

ILLUSTRATION

ESA–DAVID DUCROS/2016, © 2022 ABU DHABI SPACE DEBATE, SIPA US/ALAMY STOCK PHOTO, SHAONI BHATTACHARYA

The law in space

Rules governing space – such as they are – are decades out of date

Nigeria and Rwanda were the first African nations to sign up to the Artemis Accords on 13 December 2022

There is no set of rules or laws that encompasses all the new players in space, be they governments, space agencies or the commercial sector. However, many in the space industry say that the UN's 1967 set of rules, the Outer Space Treaty, provides a good basis upon which to build. Originally signed by the USA, Russia and the UK, it primarily ensures the peaceful use of space.

By signing it, those nations have pledged to abide by several key tenets: not to place weapons of mass destruction including nuclear ones in Earth orbit, the Moon or elsewhere in space; to provide assistance to all astronauts in distress; and that the states will be liable for any damage caused by their space objects.

One of the most recent attempts at a new agreement built upon the Treaty are the Artemis Accords, launched in 2020. The Accords aim to promote peaceful and cooperative exploration of the lunar surface, and were led by NASA ahead of its plans to extensively explore the Moon over the coming decade. To date, 23 nations have signed, but notably absent are Russia and China. The Accords contain sections governing rights to resource extraction, which Chinese space commentator Song Zhongping described as "in pursuit of colonisation and claiming sovereignty over the Moon," proving just how difficult coming to an agreement could be.

In addition, these agreements are aimed at governments and state players, and it's not clear exactly how they would govern the private companies leading the booming space industry.

of the Accords while at NASA. He said the Outer Space Treaty provides the "fundamental bones of space law" and would be a "wonderful foundation to build upon" for more present challenges.

Uneasy alliances

Many at the Space Debate raised concerns about how tensions on Earth – the war between Russia and Ukraine, for example – would affect cooperation and dialogue around space. Could such a grand treaty be reached by many, many nations in the current geopolitical climate?

Gold noted that it is possible for countries to cooperate, giving the example of the International Telecommunications Union, which globally coordinates frequency resources for satellite licences obtained by national authorities. "There were countries at war with each other and they still came together for the ITU," he said.

While many challenges were debated at the Abu Dhabi meeting, no agreements were reached other than the general acceptance of the need for discussion and cooperation. "We don't have the answers – but we needed to start the discussion somewhere," said His Excellency Omran Sharaf, chair of the UN Committee on the Peaceful Uses of Outer Space.

While the Outer Space Treaty has played a role in maintaining peace, Sharaf emphasised the importance of keeping pace with evolving technology.

"We cannot just rely on the old systems and expect that it's going to work for now or for the future," says Sharaf. "And we need to be very progressive in looking into these systems that will not just address the problem today but will address the problem 50, 70, 100 years down the line."

Despite a lack of real solutions, the event took important first steps towards finding consensus among the industry's decision-makers

Shaoni Bhattacharya is a science writer, editor and short-fiction author

A stunning image of the Orion Nebula created by combining the data from all the multi-band filters on the following pages. The image was star-aligned, processed and stretched in PixInsight before using StarNet 2 to remove the stars. They were replaced with star data from Antlia's RGB filter alone, as it produced the most natural-looking stars

Imaging with MULTI-BAND FILTERS

Imaging expert **Gary Palmer** looks at eight of the latest filters and how they perform when it comes to capturing faint and pleasing nebula detail

Over the last few years there has been an explosion of multi-band filters for astrophotographers. Used with a colour astro camera, they help to combat light pollution and make it easier to image deep-sky targets from cities. Compared to mono cameras, one-shot colour cameras also help in this regard as they save time imaging. Combining data captured with a multi-band filter and with a standard light-pollution filter allows some good creativity when it comes to processing; the colour can be changed, and stars moved from one image to another to give some very impressive results.

Here we have examined a selection of multi-band filters to look at the differences in the wavelength of light they let pass through to the camera sensor. There are dual-band filters, which mainly pass the light emission from ionised hydrogen alpha (Ha) and oxygen III (OIII) (though some are now passing sulphur II (SII) and OIII emission), which can enhance the detail within nebulae. There are tri-band filters too, which generally have the addition of passing hydrogen beta emission, useful for adding detail to areas that contain OIII.

The target we chose to image with the eight filters was the Orion Nebula; it has a good mix of gases to image and, in the outer areas beyond the Trapezium, great detail which is harder to capture with standard light-pollution filters. For each multi-band filter, we captured 40x 180-second exposures, processing this with a full set of calibration frames in PixInsight. Further processing was limited to noise control and gentle stretching, but no colour calibration, as we wanted to show what each filter produced. ▶

Gary Palmer is an astro imaging expert and the assistant director of the BAA's Technical section

ALL PICTURES: GARY PALMER

Optolong L-Ultimate dual-band 3nm filter

2-inch, £389

A good option for heavy light pollution, the L-Ultimate delivers in Ha

Released late last year, the L-Ultimate is one of the newer filters on the market and at the moment is only available in a 2-inch diameter. It's a dual-band filter aimed at Ha and OIII, letting both wavelengths through with a bandpass of 3nm. Its main advantage is its tight emission lines (OIII at 500.7nm and Ha at 656.3nm), making it possible to image in heavily light-polluted areas. It will help bring out more detail at these specific wavelengths, but it isn't suitable for faster setups, being best-suited to focal ratios of f/4 and above. For the test image on the left it gave really good results in Ha; the structural detail in the background was well-defined for a relatively short amount of capture time. There are a few halos around the brighter stars which can be reduced by lowering the gain or ISO. With more time spent capturing exposures, the filter would produce better results in both Ha and OIII, enhancing more detail around the Running Man Nebula.

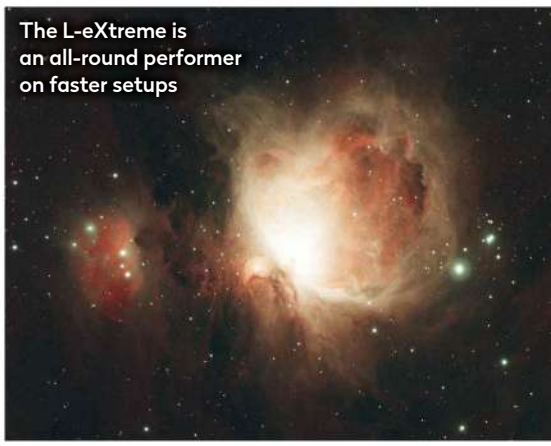
▶ **More details at bit.ly/LUltimate**

Optolong L-eXtreme dual-band 7nm filter

1.25-inch, £169; 2-inch, £239

Optolong's L-eXtreme filter has a 7nm bandpass on both its Ha and OIII wavelengths, making it suitable for faster imaging setups. Having a tight bandpass at both wavelengths makes it suitable for light-polluted areas, blocking out most light pollution. Results are very similar to other filters in the Optolong range, but at the 7nm bandpass it would take longer to capture the same amount of detail in the image (though this will vary depending on the speed of the optical system). While there is some haloing in OIII around the brighter stars, most of the smaller stars are very good. Detail in the background structures is very nice, though it will take more time to achieve more detail in the Running Man Nebula. On a cost basis it is very well-priced, so would make a good addition to most imaging systems you might have. The filter comes in 1.25-inch and 2-inch diameter formats and can be used with DSLR cameras as well as CMOS and CCD mono or colour astro cameras.

▶ **More details at bit.ly/LeXtreme**



The L-eXtreme is an all-round performer on faster setups

Optolong L-eNhance tri-band filter

1.25-inch, £129; 2-inch, £166; Canon EOS-C clip-in, £229

Given enough exposure time, faint details pop with the inexpensive L-eNhance

Optolong's L-eNhance filter is a tri-band filter that passes Ha, hydrogen beta (H-beta) and OIII wavelengths, giving it a somewhat wider bandwidth coverage than other filters. It's been around for quite some time now, but is still a really effective filter to use. With the addition of Hb the L-eNhance gives a good amount of data on targets in a short amount of time, with nearly any optical system. The structural detail in the background is a little softer than some filters, but this will improve with longer exposure runs. There's a lot of detail in the OIII areas of the test image and the Running Man Nebula is well-defined. The stars are not as tight as with some of the other filters, but this can be caused by high cloud. For combatting light pollution it is one of the least expensive filters here, making it a good addition for anyone on a tighter budget. The L-eNhance is available in 1.25-inch and 2-inch diameters for astro cameras, and as a clip-in for Canon EOS-C DSLR cameras.

▶ **More details at bit.ly/LeNhance**

The Antlia ALP-T revealed subtle Ha details but was underwhelming for OIII data

Antlia ALP-T dual-band 5nm filter

2-inch, £393

Antlia's ALP-T filter comes in 2-inch diameter and also in an unmounted format, and is not to be confused with the Highspeed 5nm version that's also available. It's a dual-band filter with a 5nm bandpass that's best suited to optical systems above f/4. The two wavelengths it passes are focused on Ha and OIII, with the OIII running slightly tighter at 500.7nm. While structural detail is there in the background of the test image, it is very subtle in Ha. Taking a closer look we can see that the halos around brighter stars are controlled very well. There is unfortunately a real lack of OIII data, which seems to be held back quite a bit. The Running Man Nebula is not well-defined and this will mean that longer exposure runs won't be a great help: adding more exposures will not bring out more OIII if it's not passing through to the sensor. Running the filter on some other targets showed an equally big drop in OIII, compared to other filters.

▶ **More details at bit.ly/ALPTfilter**

Antlia Triband RGB Ultra filter

2-inch, £205

The Triband's coating counteracts green tinging well, giving a natural look

The Triband RGB Ultra Filter is another new filter released in late 2022. What makes it unusual is the combination of transmission lines to create a natural blue in the images it captures. Most dual- or tri-band filters give quite a heavy green in the image, which takes a bit of work when processing to make look more natural. Also unlike the other filters that concentrate on emission nebulae, this filter is able to image other deep-sky objects like galaxies and star clusters. It passes Ha, SII, OIII and nitrogen II (NII); Ha at 656.3nm, SII at 671.6nm to 672.4nm, OIII at 495.9nm to 500.7nm, and NII 654.8nm to 658.3nm. When we look at the test image, we can see Antlia's clever techniques in its coating process which maximise the blue channel. Structural detail in the Running Man Nebula and the background of the image are very good, so playing around with gain and ISO settings will produce some very nice results. Testing on several galaxies showed that it is a very capable filter. It's also available at a reasonable price.

▶ **More details at bit.ly/TribandRBGfilter** ▶

ALL PICTURES: GARY PALMER

Working with multi-band filters

Here's how to include the filters in your imaging setup

Multi-band filters can be used with most astro cameras on the market and are very easy to get to grips with. Lots of telescopes have a filter holder inside the focuser, where the filters are fitted. If this is not available, a filter drawer is a good addition to make life easier. Filters can then be mounted inside and placed in the imaging train near the camera. Extra drawers can be purchased for other filters, making it simple to change them when needed.

Dust and rotation are problems we have when changing filters manually, for example if you have multiple filters for different objects.

A filter wheel is the simplest solution. All the filters can be loaded inside and then in capture-control software each filter can be individually selected. The filter wheel is fitted on or near the front of the camera in order to cut down on optical problems and reflections. It is also a great way to keep the filters safe and stored when not being used.

On our imaging setup, the filters were loaded into a ZWO filter wheel on our ZWO ASI2600MC Pro astro camera, controlled with a ZWO ASiair Plus unit. The telescope we used was a William Optics GT81 WIFD, mounted on a iOptron CEM70 mount.

In our test setup, the filters were loaded into a filter wheel on the front of a ZWO ASI2600 colour camera

IDAS NBZ dual-band 12nm filter

48mm, £275; 52mm, £298

The IDAS NBZ filter is a dual-band nebula booster filter that passes Ha and OIII, both with quite a wide bandpass of 12nm. While this will help reduce halos, it also makes the filter more usable on faster optical systems from f/4 down to f/2.

OIII emission passes at 495.9nm and 500.7nm, and Ha at 656.3nm. While slightly outside the optical system we used, on an f/2 system, it would deliver a good amount of detail in a short amount of time and, with the coatings used, it will produce very good contrast. Looking at the test image, it is a little softer than some other filters. The Running Man Nebula is starting to build some definition and the background detail is a little noisier, but that would improve with some more exposures. For users of faster systems, the NBZ is very well-priced compared to other filters in this area. It is also available in an even faster format for ultra-fast imaging systems.

▶ **More details at bit.ly/IDASnbz**

We got pleasingly strong definition and contrast, plus reduced halos with the IDAS NBZ on board

ALL PICTURES: GARY PALMER

While halos were controlled, definition and detail disappointed with Askar's Colour Magic

Askar Colour Magic 6nm dual-band filter (OIII + Ha)

2-inch, £320

Askar is one of the newer manufactures to the filter market. This 2-inch diameter Colour Magic is a dual-band filter that passes Ha at 656.3nm and OIII at 500.7nm, both with a 6nm bandpass. One of its main claims is that it produces no halos around stars. Looking at the test image, it is not as detailed as some other filters. There is a lot of OIII lacking and the Running Man Nebula is not that well-defined. The image does show decent Ha data, but it is not a stunning amount in the background and still quite noisy. Targets will need more exposure time to achieve good results. There is little to no fringing around the stars in the image, but the absence of halos has come at the cost of OIII data, suggesting there is an issue in the way the wavelength is coming through the filter to the sensor.

▶ More details at bit.ly/AskarO3Hafilter

Askar Colour Magic 6nm dual-band filter (SII + OIII)

2-inch, £320

Askar's second offering yielded OIII and SII data aplenty to work with

Askar launched its second dual-band filter in late 2022, with a change to the wavelengths it allows through. It passes OIII at 500.7nm and SII at 671nm, both with a 6nm bandpass, which gives interesting results in the captured image. SII is normally found in quad- or tri-band filters, making it hard to separate the wavelength from Ha when processing. Indeed, combining data from this filter with separate Ha-filtered data would enable a good variation in colour palettes in later processing. Looking at our test image, we can see there is a decent amount of data at OIII and SII. In OIII there is plenty of detail available to work with, and nice amounts of SII are in the image as well. Looking at the abundance of OIII in this image compared to its sister filter, the OIII + Ha (and other filters tested here), our previous note about star halos in the images appears to be backed up: it seems that in the pursuit of reducing halos there is a reduction in the amount of OIII visible in quite a few of the images.

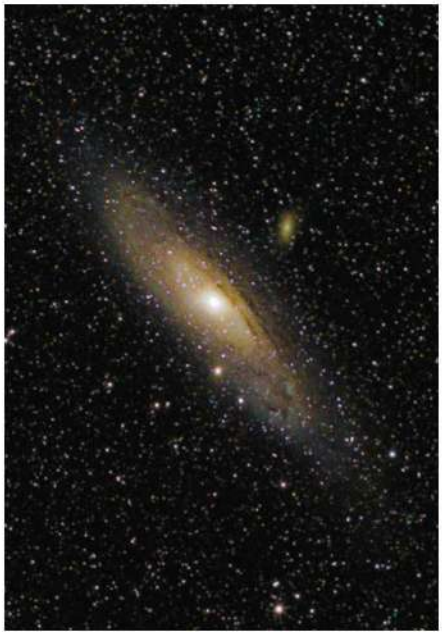
▶ More details at bit.ly/AskarS2O3filter

The fundamentals of astronomy for beginners

EXPLAINER

Master the art of averted vision

Martin Mobberley explains how to see fainter objects than you ever imagined possible



CEDIC/CHRISTOPH KALTSEIS/CCDGUIDE.COM, BERNHARD GOTTHARDT/CCDGUIDE.COM, BERNHARD HUBL/CCDGUIDE.COM, SOLAR22/ISTOCK/GETTY IMAGES, STEVE MARSH

If you're new to stargazing, a faint object like C/2022 E3 ZTF, the comet that had us all excited earlier this year, isn't the best target for a first look through a telescope – the chances are you won't see a thing. The eye is a remarkable detector, but to see faint objects like this it helps to understand both its limitations and the tricks you can use to coax the maximum out of its short-exposure capability (unlike a DSLR camera, long exposures aren't an option with the eye).

Of course there are other limiting factors. Light pollution, impatience, a poor night for seeing, and not spending long enough dark-adapting your eyes can all play a part, as can using the wrong magnification and not keeping your telescope's optics clean and well-collimated. But by mastering 'averted vision', you can train your eyes to get the most out of your observing nights and use your retina to greatest effect.

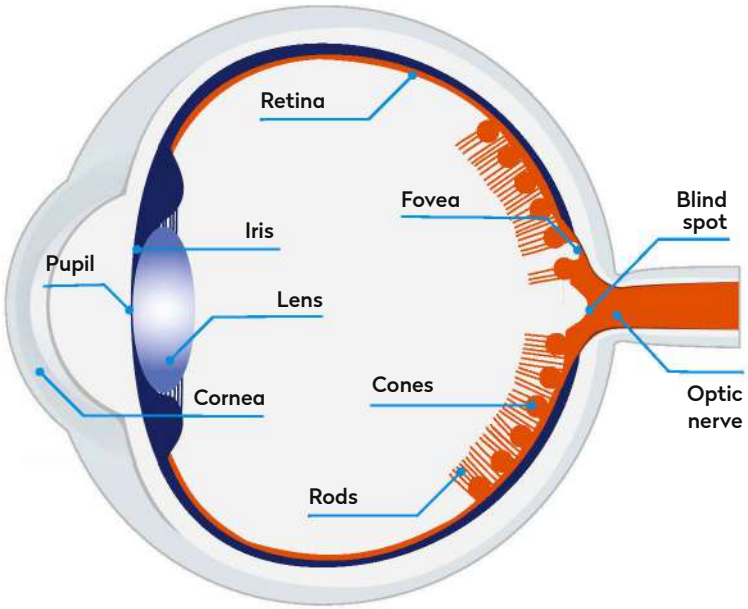
The retina is the thin layer of cells that line the back of the eyeball, where light entering from the pupil is converted into signals for the brain. The eye has two types of detector cells within the retina, called rods and cones. Rods are low-light detectors, whereas cones allow full-colour, high-resolution eyesight. The central one degree of the retina, the fovea, is packed with cones which you are using to read this sentence. Your brain creates the illusion that the whole magazine page is sharp, but in fact you are only seeing a few letters at a time at high resolution and in full colour; your eye muscles are swiftly zipping everywhere and creating the illusion.

▲ With averted vision you'll see faint targets like the Orion Nebula (left) and the Andromeda Galaxy (centre) better. For the Blinking Planetary Nebula, NGC 6826 (right), for example, looking directly at it you will only see its central star, but if you use averted vision and look to one side, you will see the nebula

Find your sensitive side

The electrochemical signals from the retina's detectors travel via neurons known as ganglion cells on their way to the brain. In the high-resolution, full-colour retina centre, one ganglion cell connects to one cone. But as you go further out and low-light rods dominate, there may be 100 rod detectors passing their electrochemical signal into just one ganglion cell; it is a case of paralleling up to improve the signal-to-noise ratio.

With so many detectors bundled together, resolution suffers badly. While the foveal cones can resolve a 60th of a degree (one arcminute), the bundled rod system, well away from the centre, might only resolve 20 arcminutes; that's not much finer than the size of the Moon seen with the naked eye.



◀ At the back of the eye lies the retina, lined with millions of light-sensing cells, rods and cones (shown here at many times actual size). These convert photons to electrochemical signals that travel along the optic nerve to the brain, where they're processed into images

The good news is that there is an optimum, ultra-sensitive, rod-packed region of the retina that you can bring into play. Here at this crucial point, the eye is about four astronomical magnitudes (40 times) more sensitive than at its centre.

To get to this sensitive area, you have to look to one side of the faint astronomical object you're trying to see: place the object you're looking at roughly 8° to 16° away from the eye's centre; 12° is a good average value for the best part. At first this will seem incredibly difficult, but it will improve with practice.

This 12° offset should be arranged so that you appear to place the object nearer to your nose. The reason for this is that the eye has a blind spot where the optic nerve leaves the retina and this blind spot is on the other side, away from the nose. Physically, it isn't – the eye's lens turns everything upside down, but we are looking at how it feels here and not how it actually is.

Martin Mobberley is an author and lifelong amateur astronomer, and served as BAA president in 1997–99

Keep it dark

Of course, when you first go outside and look through the eyepiece, you probably won't see anything. This is because your eyes aren't dark adapted. When the human eye is plunged into darkness, two things happen. Firstly, the pupil dilates (expands) to its maximum diameter. The second thing is that the amount of the chemical rhodopsin in the retina increases dramatically, many thousand-fold. So the combined effects of rhodopsin and using averted vision amounts to over 100,000 times more sensitivity than your central vision had in a fully-illuminated room before you stepped outdoors.

Dark adaptation – that is, waiting for the rhodopsin to do its job – cannot be rushed. You need to wait 40 minutes or more to feel the full effect. So, if you are planning to observe a number of faint objects, say the Orion Nebula, the Andromeda Galaxy or even the Blinking Planetary Nebula, save the faintest ones until the very last – you won't be disappointed.

Other ways to see faint targets

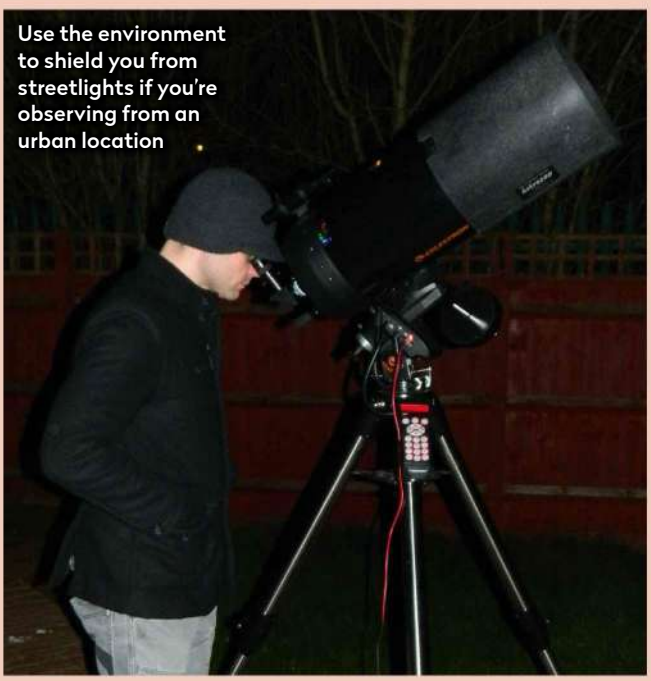
As well as averted vision, try these steps to help you observe dim targets in the night sky

Telescope
Check your telescope is in good working order, with clean optics. If it's a reflector, make sure that its mirrorrs are accurately collimated.

Eyepieces
High-quality eyepieces will maximise your chances of seeing faint objects. A rubber eyeguard will exclude stray light.

Weather check
The best crystal-clear nights often come when a cold front or a northerly air stream moves down the country. Check the Met Office's weather maps for the latest forecast.

Dark site
Darker skies are better, of course, but if yours aren't you can block out streetlights by carefully positioning your scope or using fence panels as shields.



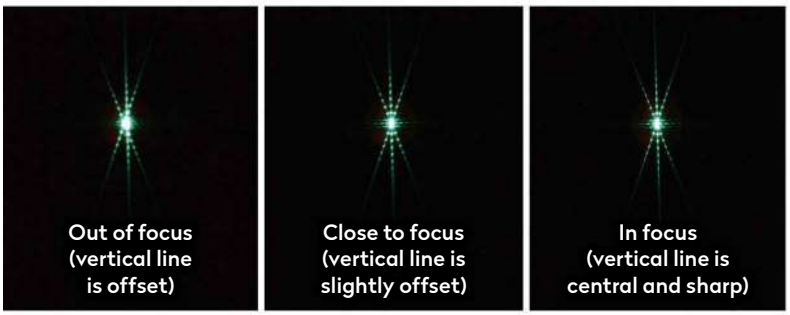
Use the environment to shield you from streetlights if you're observing from an urban location

Build a Bahtinov mask

Make an astrophotography focusing aid to fit any telescope

Mark Parrish is a bespoke designer based in West Sussex

The completed mask slips over the front of your telescope



Out of focus (vertical line is offset)

Close to focus (vertical line is slightly offset)

In focus (vertical line is central and sharp)

▲ **With the mask in place, light from a bright source (for testing we used a green LED) produces three crossing spikes which are aligned when perfectly focused**

Achieving focus is arguably the most important aspect of a successful image. This month's project is a focusing aid to help you achieve pin-sharp stars and therefore pin-sharp images. The design, developed by astronomer Paul Bahtinov, is a mask that makes use of diffraction, an optical effect that happens when light passes through small openings. Diffraction effects can be observed with a Newtonian telescope that has a 'spider' support for the secondary mirror, or a camera lens with an iris that has straight edges – in both cases, bright stars appear to have lines (called spikes) radiating from them.

Our mask has three sets of diffracting slits through which the starlight passes. On one side, two sets of angled slits produce a cross pattern, while the straight slits on the other side create a line that passes through the cross. When the image is properly focused, this line passes exactly through the centre of the cross, but when unfocused it is offset to one side.

Cutting it fine

Most DIY versions of such masks are made from card, but this design is slightly more robust and should last longer. However, it's still easy to make, using just a few basic materials, a craft knife and glue. The mask panel is cut from a sheet of thin craft foam and the sleeve is built up from strips of cork. These were bought from our local hobby and craft store. A very sharp knife is essential for a neat mask, so pop a new blade in, use a cutting mat to protect the tip, and make the mask panel before cutting the cork strips.

There is no need to work out the design of the slits because there's an online tool that does it all for you. Go to **bit.ly/bahtinovmask** and type in your telescope's focal length and aperture. If your telescope has a central obstruction, add the diameter of this too. The tool generates a CSV file that can be printed from various applications, including MS Word and Google Chrome.

Once your mask is completed, you can use it by taking a series of images of a convenient bright star (or use live view) and adjusting the fine focus. Once you have the line and cross aligned, lock your focus, remove the mask, and reposition the scope to take an image of your desired deep-sky object.

What you'll need

- Scalpel or craft knife, cutting mat, safety rule, pencil
- Thin, black craft foam (size to suit tube diameter), thin cork sheet
- Black spray paint, PVA glue, masking tape, low-tack glue or spray mount
- Rubber bands, clothes pegs

ALL PICTURES: MARY MCINTYRE

Step by step

Step 1

Remove the dew shield to work on, if possible. If not, protect the optics with a clean, soft cloth and make sure that the telescope can't roll off the table. Measure the diameter of the dew shield or main tube. Protect the tube with some masking tape.

Step 2

Enter your telescope's specifications into the online mask generator. Download the file and print. Use low-tack glue to fix the printout to the craft foam. With a very sharp scalpel or craft knife cut out the slits. Peel off the remaining paper.

Step 3

Cut enough 40mm-wide cork strips to wrap around the tube three times. Trim and fix the first strip around the tube, holding the ends together with tape. Apply PVA glue to the next two layers and wrap them round. Secure with rubber bands until dry.

Step 4

Slip the whole ring up by about 15mm. Cut three 10mm-wide cork strips. Carefully use PVA to glue these inside the cork ring, forming a lip. We used clothes pegs to clamp them. Wait until all the glue is dry before removing the ring from the tube.

Step 5

In a ventilated space, add a few layers of black paint to provide some protection against moisture and make it more hard-wearing. We left the inside as natural cork where it touches the paintwork of the tube, making it easier to slip on and off.

Step 6

Once the paint is dry, you can insert the mask into the underside of the lip. You may leave this loose in case you want to experiment with different mask patterns, but when you are happy with the result, add a few drops of glue to secure the mask in place.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY

CAPTURE

Experiments with Venus

Try out these activities while the Evening Star is shining bright in our skies

ALL PICTURES: PETE LAWRENCE

Venus is well-placed in the evening twilight this month, an intense blaze of light, difficult to miss in clear skies. It's an interesting object astronomically, showing subtle atmospheric markings through the eyepiece, as well as displaying striking changes in phase and apparent diameter.

It's interesting for another reason too. Being so intensely bright – the brightest of all the planets – it's essentially a point source at low magnification, and ideal for demonstrating experiments with light. When placed in a dark sky, it's possible to experience its light casting a shadow – okay, it's a dim shadow, but it's one that can be photographed. Being very close to a point light source, the shadow cast is really sharp and well-defined too.

To record this elusive effect, you'll need to be somewhere where there are no other light sources. Even a bright sky can interfere. A west or northwest-facing window is ideal, as long as you can turn all of the lights off. If you can't do this, use a large cardboard box with the opening pointed at Venus. Either way, you'll need a screen on which the shadow will be cast. This can be as simple as a light-coloured wall or several large white sheets of paper.

▲ You can produce diffraction spikes by stopping down a camera lens, using Venus as the bright light source. As shown here with both the Moon and Venus, the spike quality can vary between lenses

Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

You'll need a shadow-casting subject as well. This can be a shape cut from card pasted on a window or suspended in front of the box. Then it's simply a case of pointing a camera at the screen, focusing and taking your shot. A high ISO is recommended to keep the exposure times short; take too long and the razor-sharp edge of the shadow will blur as Venus moves relative to the horizon.

Make a rainbow

Another interesting effect to see with Venus is something which is a nuisance for planetary imaging: atmospheric dispersion. This is caused by the light-dispersion quality of our atmosphere. Essentially, the atmosphere acts like a giant prism, refracting light that passes through it. The thicker the atmospheric layer, the more bending that takes place. In other words, the bending is greater at lower altitude. As white light passes through the atmosphere, different wavelengths of light get refracted by different amounts, resulting in an object's light being spread into a small spectrum. The effect is noticeable around the edge of the Moon, but the brilliance of Venus means it's easier to stay with the effect at lower altitude. Using a long-focal-length lens or telescope, it's possible to see Venus completely smear into a small rainbow of colour.

Finally, the planet's brilliance and point-source nature make it ideal for experimenting with diffraction. A low-power reflector will create diffraction spikes easily and some general photographic lenses can produce them when the lens aperture is stopped down. Alternatively, if using a refractor, cotton thread placed over the front aperture is a great way to show these physical effects with the Venusian light.

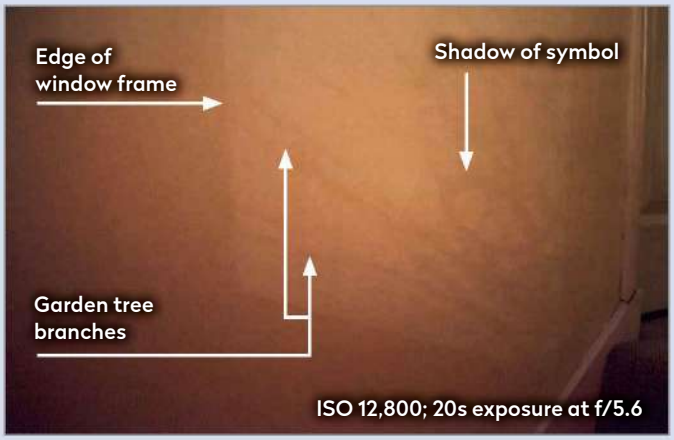
Equipment: DSLR camera with lens, a tripod or, preferably, a tracking mount

✉ Send your images to:
gallery@skyatnightmagazine.com

Step by step

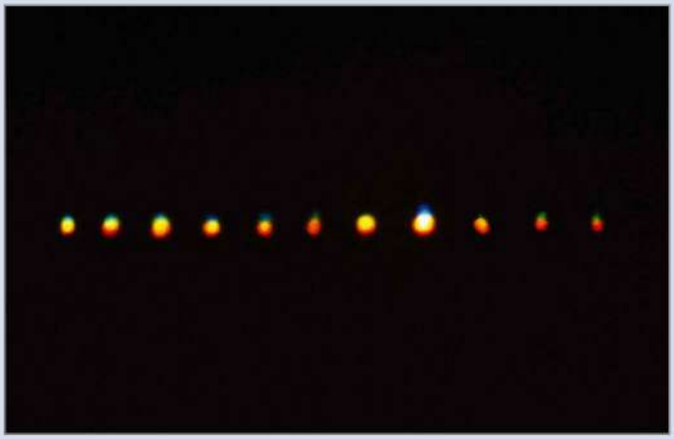
STEP 1

A west or northwest-facing window is ideal for capturing the shadow of Venus. In a darkened room, attach a shape to a window pane to act as a shadow caster – in this case a cardboard cutout of the symbol of Venus. The line from Venus through the target should ideally end up on a flat 'screen' wall.



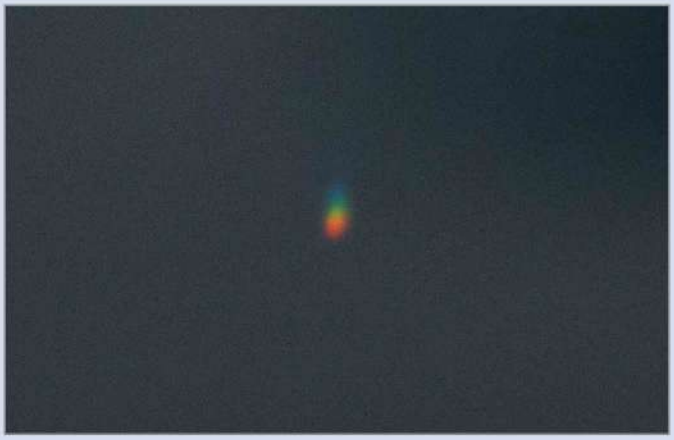
STEP 2

Despite Venus being such a brilliant planet, its shadow is still dim and will require an extended exposure. A mid to high ISO and low f/ number are essential. In this example, there was a tree between Venus and our shadow target. An exposure of 20 seconds was required. If exposures are too long, the shadow edges will blur.



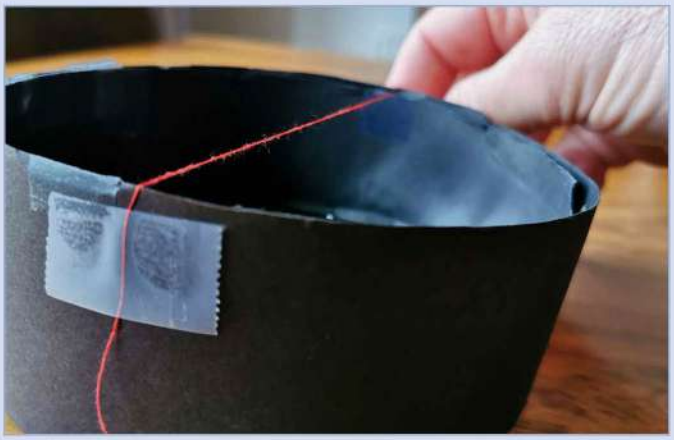
STEP 3

This sequence, imaged through a low-power telescope as Venus was setting, shows the effects of atmospheric dispersion. Venus's light is spread into a spectrum, varying in intensity according to atmospheric stability (seeing). Just before setting, the green edge of Venus detached, creating a Venusian 'green flash'.



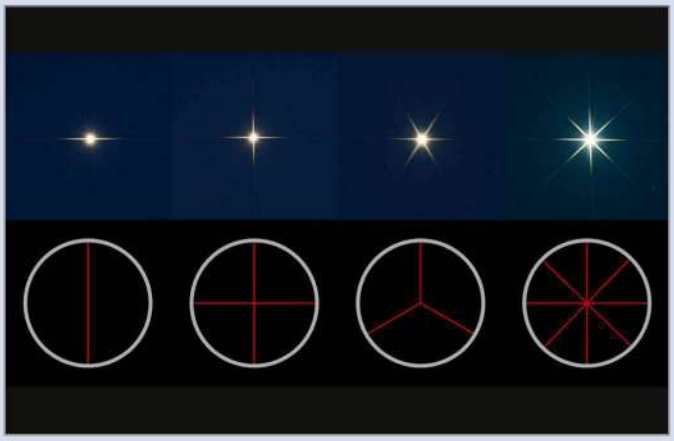
STEP 4

Although dispersion is easier to record with bright Venus, it's not the only object to show it. Mercury is well-placed this month too. It appears brightest at the start of the month, but its proximity to the Sun means you'll typically need to record its colour spread against twilit skies, as shown here.



STEP 5

A refractor can be made into a diffraction generator by creating a cardboard collar around the front of the scope and attaching cotton 'vanes' in various orientations. Attach a camera to the scope and, using a mid-value ISO, focus (the spikes are useful for this) and take a shot of Venus, using an exposure of a few seconds.



STEP 6

Start off with a simple cotton line across the telescope's aperture diameter and go from there. A four-vane pattern generates eight spikes, but half are coincident with the other half, so you only see four. Three vanes arranged at 120° intervals don't have this issue and here you'll see six vanes with 60° between them.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Speed up your workflow

Save time by automating common processing steps like boosting contrast and reducing noise

▲ Chris's initial image of the North America Nebula (left) and the final processed image after using automated actions (right). These actions take some of the hassle out of common processing steps like making starless images, smoothing and enhancing colour

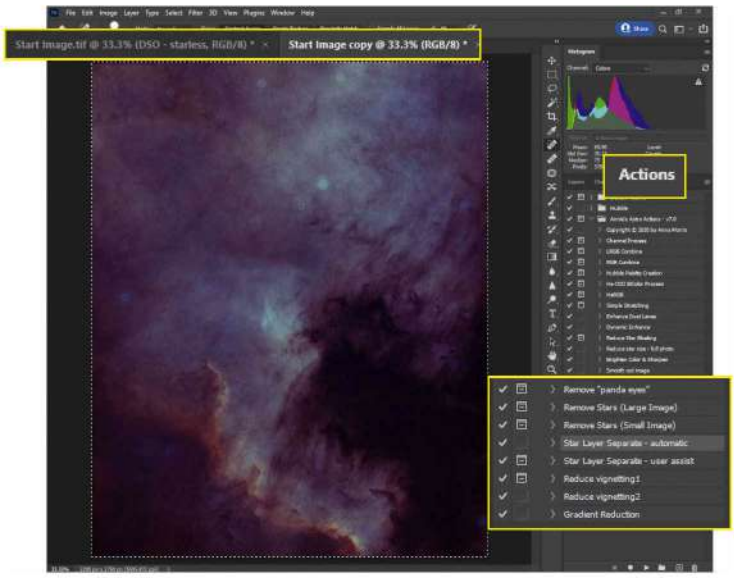
The world of astrophotography can be daunting, and learning image processing can be a particularly steep learning curve. Any help that can boost our editing skills is a bonus. In Adobe Photoshop, 'actions' can help to overhaul your processing workflows. These are a set of steps that can be saved and replayed on future images to, for example, boost contrast or reduce noise. You can also purchase actions created by someone else.

One such set is Annie's Astro Actions, a comprehensive set of 24 different workflows that can guide you through the editing process, from simple step-by-step guides, and combining mono images into RGB or the Hubble Palette, to stretching and star removal. A full list of actions is available to view at **www.eprisephoto.com/astro-actions** prior to purchase.

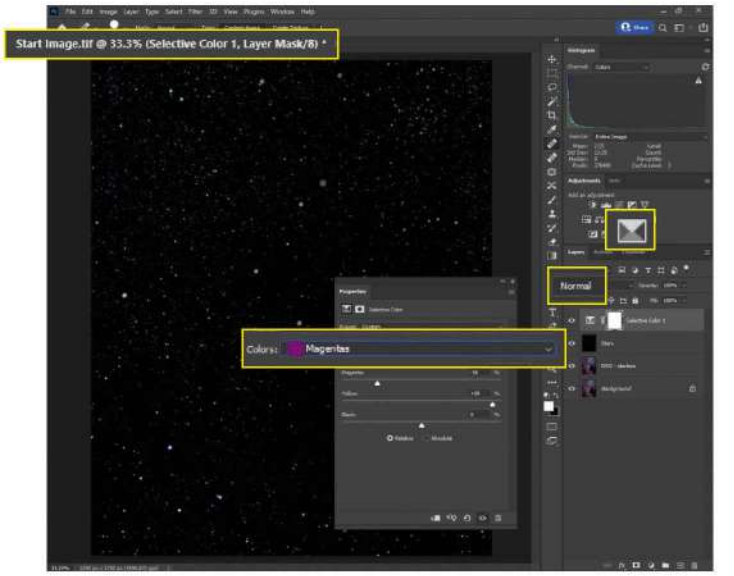
Once purchased, download Annie's Astro Actions to your PC and save it to a location of your choice. Open Photoshop and ensure your 'Actions' tab appears (see screenshot 1). If it doesn't, click on the Windows menu and tick 'Actions' from the list. Under the actions panel, click on the three horizontal lines at the top right and select 'Load actions' from the menu to open a file explorer window. Navigating to where you saved your actions file, select it and click 'Load'. You will see all the actions appear as a list within the actions panel.

We will show how we used Annie's Astro Actions to process our image of the North America Nebula, NGC 7000. The first action we applied was 'Star layer separate – automatic'. This removed the stars from our image and created a duplicate image that contained just the stars. To apply the action, we selected 'Star layer separate – automatic' from the list and then hit the play icon at the bottom.

ALL PICTURES: CHRIS GRIMMER


Start Image.tif @ 33.3% (DSO - starless, RGB/8) *
Start Image copy @ 33.3% (RGB/8) *
Actions
Remove "panda eyes"
Remove Stars (Large Image)
Remove Stars (Small Image)
Star Layer Separate - automatic
Star Layer Separate - user assist
Reduce vignetting1
Reduce vignetting2
Gradient Reduction

▲ **Screenshot 1: 'Star layer separate – automatic' created the starless image above showing only the nebula ready for processing, and a duplicate image that contained just the stars**



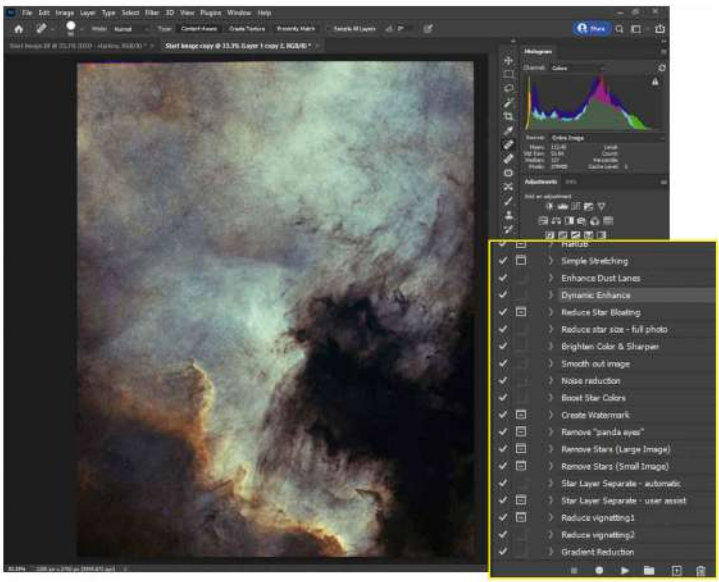
◀ **Screenshot 3: Working on the stars image to enhance their colours with the 'Selective colour' sliders. This was done by eye until we were happy with their appearance**

3 QUICK TIPS

1. You can apply actions more than once.

2. Create a new layer before applying actions (hold Shift + Ctrl + Alt, then press 'N' and then 'E').

3. Apply the 'Star layer separate' action before applying the 'Simple stretching' action, to stop stars from bloating.



▲ **Screenshot 2: The image after enhancing the nebulosity and dust lanes through smoothing, brightening colours, sharpening, reducing noise and stretching**

With the nebula and stars separated into two images, we could work on NGC 7000 without bloating the stars. The separation process left some marks around where the largest stars were, so we used the spot healing brush to remove them.

Ready for action

All of Annie's actions are run by selecting the action from the list and then hitting the play icon. First we used 'Dynamic enhance' which brightened the nebula and added contrast. We then applied 'Brighten colour & sharpen' which further enhanced the nebulosity.

'Enhance dust lanes' brought out the finer details and sharpened the dusty areas. Sharpening the image added noise, so we then chose 'Noise reduction' to reduce this, followed by 'Smooth out image' which softened our nebula. The final action was 'Simple stretching'. This action showed us, via helpful on-screen instructions, how to stretch our data and balance the colours using levels and curves. Screenshot 2 shows the effect of these actions.

With our nebula image now looking good, we clicked over to our stars image tab (highlighted, screenshot 1). As this image was separated before we applied colour correction, the star colours needed adjusting. We used 'Selective colour' to edit each colour channel separately (see screenshot 3). Adjusting the sliders under the cyan, magenta and yellow channels allowed us to create a more natural star colour. This needed to be done by eye. You may have to apply and then edit each colour multiple times until you are happy with the appearance of your stars.

Once both of our images were processed, we needed to recombine them. Starting on the image of our stars, we flattened the image (Layer › 'Flatten image'), then clicked Edit › 'Select all' to highlight the entire image. With Ctrl + C we copied our image. We opened our nebula image from the top tab and pressed Ctrl + V to paste our stars. This created a new layer with our stars. We switched our blending mode from 'Normal' to 'Screen' and a combined image appeared.

Our final image now contained the processed nebula and star images and, as a final task, we applied the noise reduction action one final time before saving. You can see the final result on the page opposite.

Chris Grimmer is an experienced astrophotographer and photographer specialising in infrared images

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

△ Comet C/2022 E3 ZTF

PHOTO OF THE MONTH

Tim Jackson, Cheltenham, Gloucestershire, 24 January 2023

Tim says: "Comet C/2022 E3 ZTF last visited us 50,000 years ago. This really was a once in a lifetime opportunity to image it. Having been in the news and all across social media, I was inspired by some of the great images I had seen. I managed to wake up at 4am to find it in the early morning sky."

Equipment: ZWO ASI294MC Pro camera, William Optics Zenithstar 73 III APO refractor, Sky-Watcher EQ5 Pro mount
Exposure: 2h
Software: PixInsight, Affinity Photo

Tim's top tips: "Shooting comets isn't easy as they travel faster through the sky than the stars. Once I had it framed in my field of view, I guided on the stars and set a plan in my ASIair Wi-Fi controller for two hours of 120-second light frames. The problem is the comet will blur or the stars will trail, depending on how you image. Processing the image was probably the hardest and longest task I've undertaken since taking up imaging three years ago. I used all the tools available in PixInsight and, after taking some advice, I chose to remove the stars from every light frame first, using StarXTerminator. This took around eight hours. I was then able to use the comet alignment tool in PixInsight to process the comet with a starless background. Following this I recombined the stars into the final image, and did the usual curves adjustments and denoise processes."

The Moon ▷

Sonia Turkington, North Reddish, Greater Manchester, 25 January 2023

Sonia says: "I love a crescent Moon. I find it hard to find the right light balance with these photos to get a good one, but I got it right with this one."

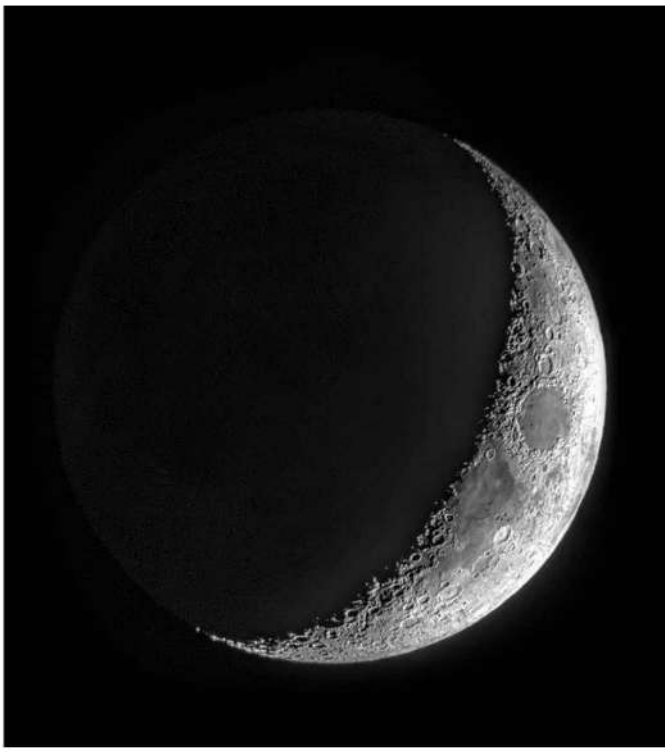
Equipment: Google Pixel 6 smartphone, Sky-Watcher Skyliner 250PX 10-inch Dobsonian **Exposure:** ISO 53 f/1.9, 1/26" **Software:** Google Photos

◁ The Heart Nebula

Rachael and Jonathan Wood, Auckley, South Yorkshire, 4–18 January 2023

Rachael says: "When Jonathan and I got our new camera, we knew the perfect target. This nebula has so much structure to offer and the Hubble palette really brings this to life."

Equipment: ZWO ASI294MM Pro camera, Sky-Watcher Evostar 80ED refractor, Sky-Watcher AZ-EQ6 GT mount **Exposure:** 12.5h **Software:** Photoshop

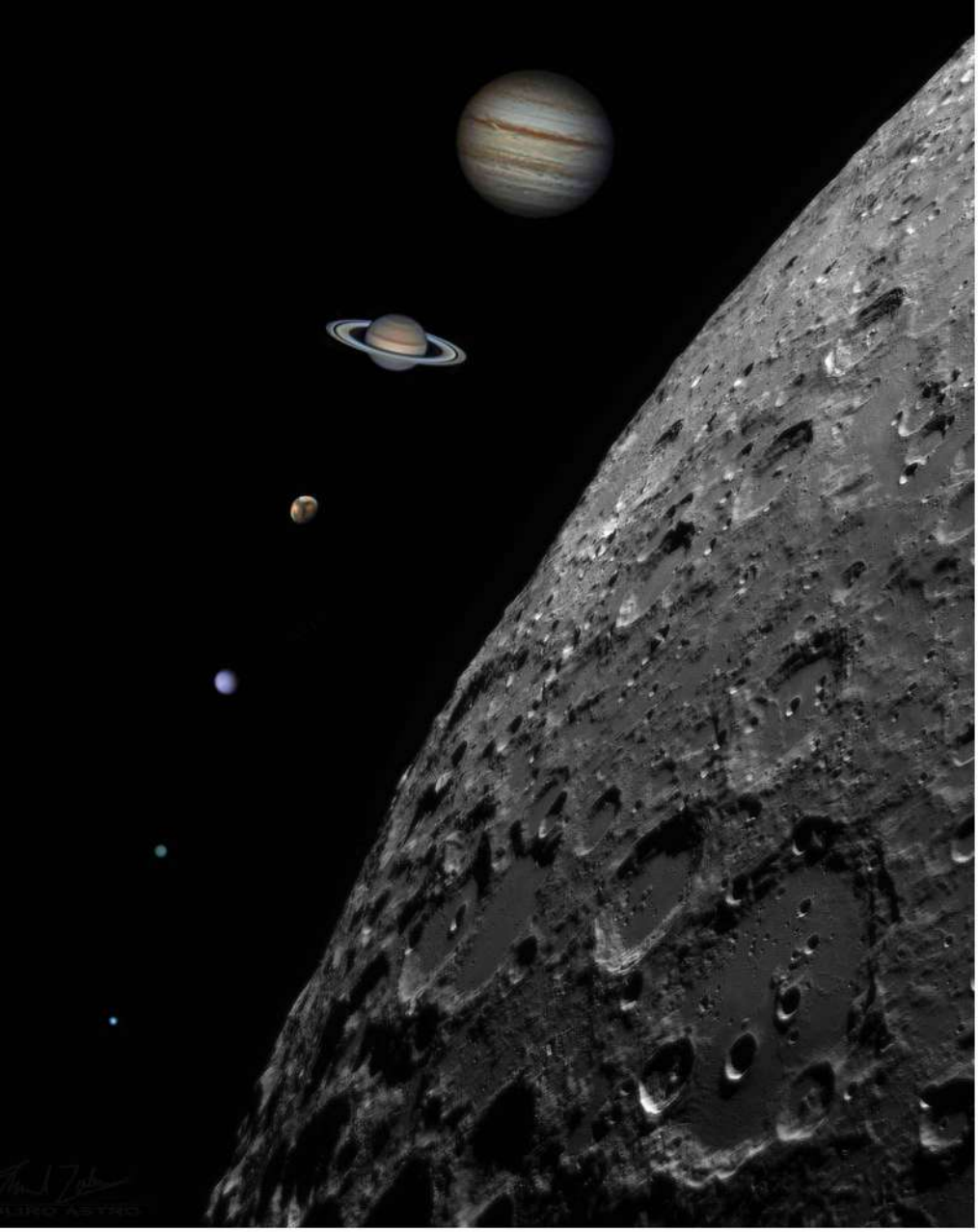


◁ Aurora

Rebecca Saxton, Haverhill, Suffolk, 27 February 2023

Rebecca says: "I went to Iceland in January with the hope of seeing the aurora, but it was cloudy all week! I was planning a trip to Norway when my aurora app sent me a notification, then I saw a Tweet saying they were visible from Norfolk. Imagine my surprise when they appeared right on my doorstep."

Equipment: Nikon D750 DSLR, 24–70mm f/2.8 lens **Exposure:** 6" **Software:** Lightroom



△ Six planets (plus the Moon) in one night

Daniel Zoliro, Chouteau, Oklahoma, USA, 19 August 2022

Daniel says: "I got a wild idea to see how many planets I could capture in one night, using the same gear. All of the images were captured using the lucky imaging technique."

Equipment: ZWO ASI174MM camera, Celestron C9.25 Schmidt-Cassegrain, Sky-Watcher EQ6-R Pro mount
Exposure: Various, 8ms–20ms **Software:** FireCapture, AutoStakkert!, PixInsight, Photoshop

The afternoon Sun ▷

Rob Lyons, Vancouver, Canada, 14 January 2023

Rob says: "It was cloudy here in Vancouver for three months straight, but one day we got a break and I made my first astronomy image of 2023, the Sun at 2pm."

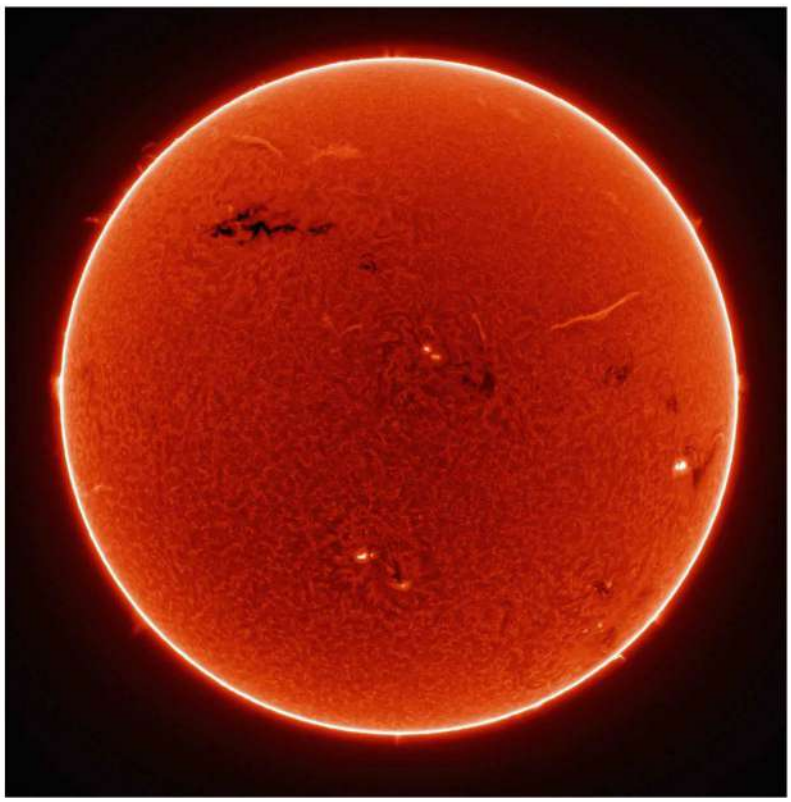
Equipment: ZWO ASI533MM Pro camera, DayStar Solar Scout SS60-ds H-alpha solar telescope, Sky-Watcher SolarQuest mount
Exposure: 45", best 24 frames stacked
Software: AutoStakkert!, ImPPG, PixInsight, Photoshop

△ NGC 2359, Thor's Helmet

Stephanie McNaughton, Red Rock, Arizona, USA, 21 January 2023

Stephanie says: "Thor's Helmet is one of my favourites. I know it isn't as extravagant as Orion, but it is so beautiful. As an aspiring astrophotographer, I'm proud to be able to send you this image."

Equipment: ZWO ASI294MC Pro camera, Celestron 8-inch Rowe-Ackermann astrograph, Vixen Sphinx SXP mount
Exposure: 3h **Software:** DeepSkyStacker, PixInsight, Photoshop



The Jellyfish Nebula ▷

Neil Wilson, Terrington St Clement, Norfolk, 21 January 2023

Neil says: "This nebula has been on my list for a while now, and when the opportunity arrived, I had to grab it. I was particularly pleased with the amount of structure that was revealed."

Equipment: Altair Hypercam 26C camera, Celestron 9.25-inch EdgeHD aplanatic Schmidt-Cassegrain, Sky-Watcher AZ-EQ6 mount **Exposure:** 1h
Software: NINA, APP, Starnet++, Photoshop

▽ Aurora

Karl McCarthy, Mynydd Illtud, Brecon Beacons, 26 February 2023

Karl says: "There were reports that a strong aurora was possible, so I made sure my camera bag had everything ready to go if the forecast came good. I drove 30 minutes to Mynydd Illtud, set up my camera and, to my excitement, from the first shot the aurora was visible."

Equipment: Nikon D850 DSLR, Sigma 35mm f/1.4 Art lens, Giottos 8254 YTL tripod **Exposure:** ISO 1600 f/1.8, 8"
Software: Photoshop, Topaz DeNoise

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Whether you're a seasoned astrophotographer or a beginner just starting out, we'd love to see your images. Send them to us at www.skyatnightmagazine.com/send-us-your-astrophotos

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We've teamed up with Modern Astronomy to offer the winner of next month's Gallery a Hama lens pen, designed for quick and easy cleaning of telescope optics, eyepieces and camera lenses. It features a retractable brush and non-liquid cleaning element. www.modernastronomy.com · 020 8763 9953

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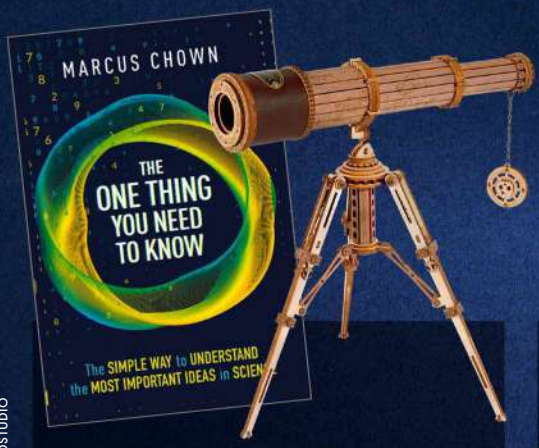
86

Big on aperture but compact in size, we put Explore Scientific's G400 15x56s to the stargazing test



PLUS: books on Stephen Hawking's final theory, neutrinos, big science ideas and more, and our roundup of astro gadgets

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★☆ Very good
★★★☆☆ Good ★★☆☆☆ Average ★☆☆☆☆ Poor/avoid

@THESHED/PHOTOSTUDIO

FIRST LIGHT

Explore Scientific G400 15x56 roof prism binoculars

Satisfyingly sturdy, this pair fits the bill for moongazing and sharp, colourful stars

WORDS: STEVE TONKIN

VITAL STATS

- **Price** £329
- **Optics** Fully multi-coated
- **Aperture** 56mm
- **Magnification** 15x
- **Prisms** Schmidt–Pechan roof, BaK-4 glass, phase-coated
- **Angular field of view** 4°
- **Focusing** Centre focus
- **Eye relief** 16mm
- **Interpupillary distance** 61–70mm
- **Weight** 1.1kg
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.**telescope house.com

ALL PHOTOS: @THESHED/PHOTOSTUDIO

Small and light enough to be easily portable and held in the hands for short periods, but also with sufficient aperture and magnification to reveal more detail than popular hand-held binoculars like 10x50s, 15x56 binoculars occupy a special niche. We were eager, then, to see how Explore Scientific's G400 15x56s performed.

Taking them out of their packaging, our first impressions were of robustness and compactness. This is due in part to their heft and the substantial untextured (but not slippery when dew-dampened) rubber armour. The smoothly operating hinge has a satisfying resistance to adjustment, which should prevent you from accidentally resetting the interpupillary distance.

The centre focus wheel is also silky-smooth in operation and has no backlash at all. It takes two complete turns of the wheel to get from 4.5m close focus to slightly beyond infinity focus at the other extreme. This slow and smooth focusing means that it is extremely precise, which makes it easy to find the point at which the target object snaps into focus. The 'beyond infinity' focus enables people with mild short-sightedness to use the binoculars without glasses if they wish. The right eyepiece adjustment has a range of +/-3 dioptres, so the binoculars will tolerate some focus disparity between your eyes.

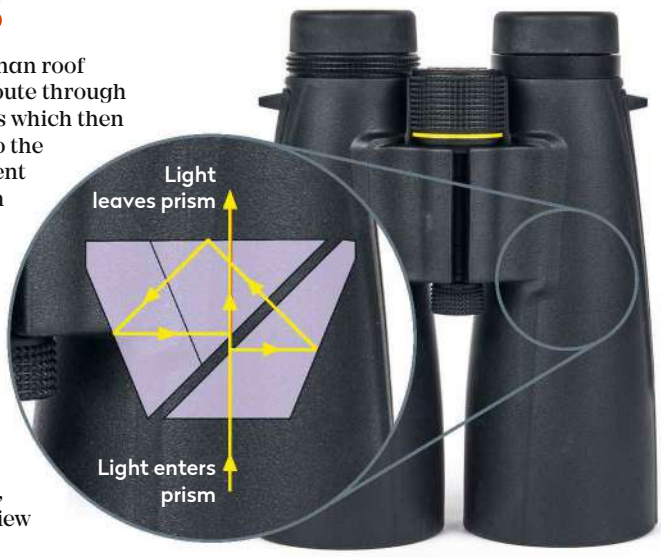
Twist-up eye-cups

We found that the 16mm eye relief was just sufficient to enable us to see the full field of view when wearing glasses with the binoculars' eye-cups twisted fully down. The eye-cups also click into a definite half-way up position, and if you use this it will not easily slip. The focus wheel is at the eyepiece end of the hinge, so if you hold the binoculars by the objective end of the tubes (which is recommended to reduce shake when observing terrestrial and low-elevation targets), you will need to move a hand to refocus. This ▶

Prism phase coatings

Explore Scientific's G400 15x56s use Schmidt–Pechan roof prisms. With these prisms, for part of the light's route through the system it is split and takes two different paths which then recombine before passing to the eyepieces. Due to the wave nature of light, the rays from the two different optical paths are consequently out of phase when they recombine. If this phase difference isn't corrected, the result is an image that suffers from reduced colour rendition, sharpness and contrast.

Like all the best roof prism binoculars, the prisms in the G400 15x56s have the appropriate surfaces coated with what are called phase coatings. These ensure that the split rays are in phase when they are recombined so the negative effects of splitting and recombining the rays don't occur. The result is faithful colour rendition, excellent sharpness in the middle of the field of view and strikingly good image contrast.



Neck strap

The padded part of the neck strap can be unclipped from the rest of the strap easily, so it needn't get in the way when you mount the binoculars. The lens covers tether to the part of the strap that remains attached to the binoculars, so they remain conveniently at hand.

Waterproof and nitrogen-filled

Although we don't do astronomy in the rain, binoculars can be affected by dew, and mounted binoculars are particularly prone to this. The waterproofing prevents dew ingress which could result in fungal or algal growth, and the dry nitrogen filling means that there is no internal oxygen to cause oxidative corrosion.

Tethered lens caps

The objective lens caps and the rainguard-type eyepiece caps can be tethered to the binocular's neck strap. This means that they are always conveniently at hand when you need them and unlikely to get mislaid. They fit very well so won't come off accidentally and expose your optics to damage.

Fully multi-coated

In order to get the full benefit of the light gathered by the 56mm-diameter objective lenses, as much of it as possible needs to be transferred to your eyes by the optical system. The dielectric anti-reflective multi-coatings ensure that as much light as possible is transmitted by the lens surfaces.

▶ inconvenience will be unlikely to occur when you are using them for high-elevation targets, when it's better to hold them closer to the eyepiece end.

Binoculars like this are far more effective when they are mounted. There is a threaded socket for a tripod adaptor at the end of the hinge. At 56mm these are near the upper limit for aperture in roof prism binoculars of this design, so there is very little room between the tubes, and you will need to choose a very narrow tripod adaptor, ideally the type that clips onto a captive pin in the socket.

Ready and steady

For testing, we mounted them on a monopod with a joystick head. The anti-reflective coatings on the transmissive surfaces and phase coating on the prism roofs combined with the precise focus to give sharp images that were bright and had good colour fidelity. Chromatic aberration, which manifests as coloured fringes on bright objects, was very well controlled in the middle of the field of view but became more apparent near the periphery.

Stars were very sharp in the central 50 per cent or so, and only became fuzzy near the edge. This made them ideal for scanning colourful clusters, such as the Meissa (Lambda Orionis) Cluster, where even subtle variation in colours were immediately apparent. Further south, Collinder 70 (the cluster that includes Orion's Belt) overflowed the 4° field of view, but the chains of stars really came to the fore. On to the Orion Nebula, M42, where its texture was immediately apparent, and we could resolve three Trapezium stars.

Turning to the Moon, the lunar terminator showed a lot of detail and remarkably little false colour near the middle of the field of view. We did notice a bit of glare in the tube nearest the Moon when it was just to the side (but not above or below) the field of view, but it was not apparent when we were observing the Moon itself.

Explore Scientific's G400 15x56 binoculars would suit someone who already has smaller hand-held binoculars but is looking for an additional, well-made, compact and robust pair for travel. Suitable for both astronomy and general use, overall we found them a joy to use.

Well-designed case

The lightly padded case has two internal pockets for storing a cleaning cloth, tripod adaptor (pictured below) and other accessories. It can be closed with a hook-and-loop fastening flap for convenience or a zip for more security, and it has both a shoulder strap and a belt/harness loop as carrying options.

ALL PHOTOS: @THESHED/PHOTOSTUDIO

VERDICT

Build & design	★★★★★
Ease of use	★★★★½
Features	★★★★½
Field of view	★★★½☆
Optics	★★★★½
OVERALL	★★★★½

KIT TO ADD

1. Bresser binocular tripod adaptor deluxe

2. BX-5 Pro video tripod

3. Bresser smartphone universal adaptor

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Our experts review the latest kit

FIRST LIGHT

Serif Affinity Photo 2

Well-priced image-editing software that features dedicated astrophotography tools

WORDS: DAVE EAGLE

VITAL STATS

- **Price** £69.99 macOS or Windows; £19.99 iPad; £169.99 for complete Affinity Suite on Universal Licence
- **Updates** Free until next version released
- **System requirements** Windows 10 & 11, macOS 10.15, iPadOS 15; PC with Direct3D level 12.0-capable card; Mac with Apple silicon M1/M2 or Intel processor; 8GB RAM; 1280x768 display
- **Developer** Serif
- **Email** affinity@serif.com
- **www.affinity.serif.com/en-gb/photo**

Serif's Affinity Photo software was released in 2015 and has since been regularly updated with new features. Several useful astrophotography tools were added in 2021, including image stacking, star alignment, and background and gradient removal. Version 2, which we're looking at here, is the latest big upgrade and was released in November 2022. With ease of use and an extremely affordable price, it will certainly entice many astrophotographers desiring a single package that does image sub-stacking and post-processing, and that won't break the bank.

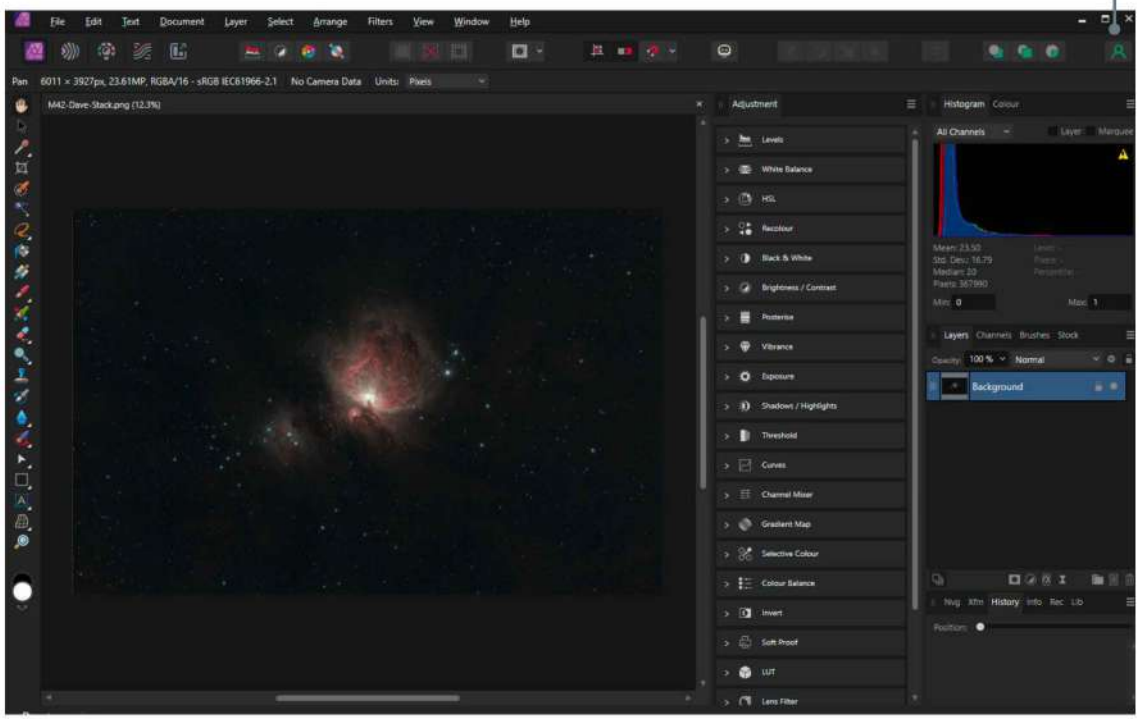
We liked Affinity Photo 2's one-off payment user licence model, not locking you into paying a long-term, monthly subscription. There are licences for PC, Mac and iPad, plus a Universal Licence that allows the full Affinity Suite to be installed on multiple machines with different operating systems. To try out the software before buying, Serif offers a 30-day trial.

The software downloaded easily, flawlessly installing on the PC and Mac computers we tried. If you already own the older version of Affinity Photo, installing Affinity Photo 2 won't overwrite it. Updates were prompted, downloaded and installed without issues.

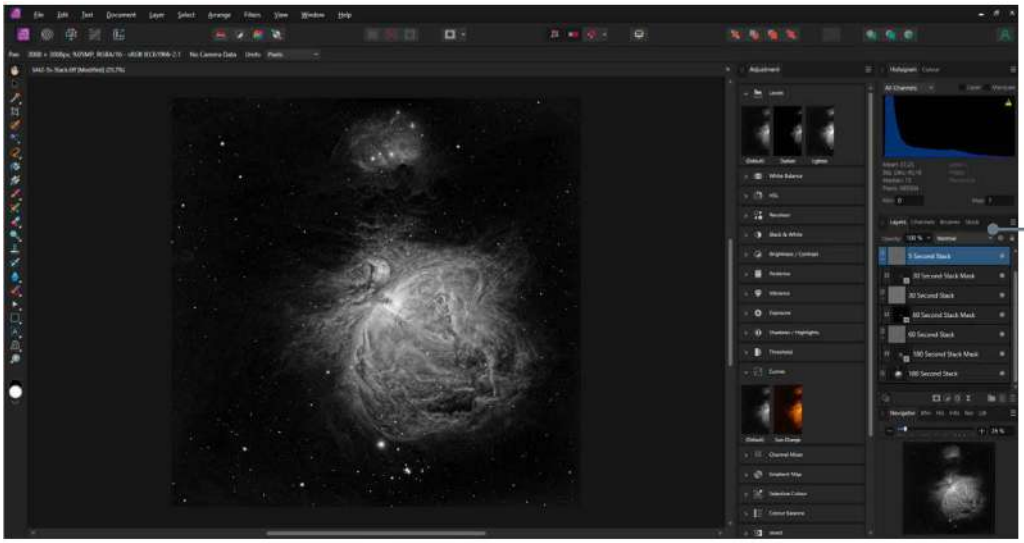
On opening Affinity, the user interface looked a little different to the previous version, but very similar to most image-processing software. It is intuitive to use, with a menu bar at the top and a toolbar on the left. There are also lots of tabs to access the different

User interface

The interface is clean and clearly set out, with the menu at the top and tool buttons to the left. Several guides are visible on the right: the live histogram, layers making up the image below that, and 'History' at the bottom to help you retrace your steps should you go wrong.



ALL SCREENSHOTS: SERIF AFFINITY/DAVE EAGLE

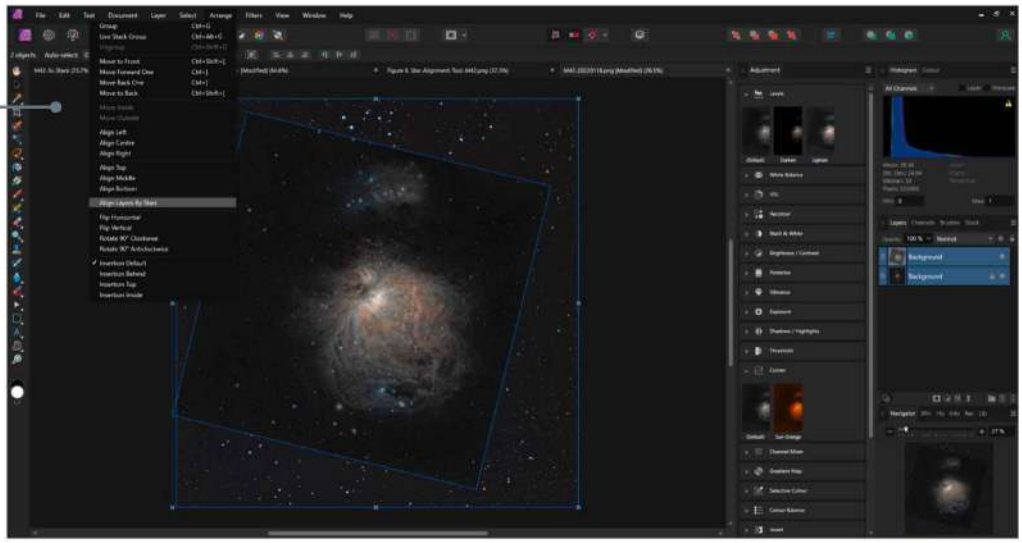


Layer masking

This technique enables you to combine differently exposed images to produce a balanced image, where the brighter portions of the object are not over-exposed. In this example, we layer-masked four different hydrogen alpha exposures of 5, 30, 60 and 180 seconds of M42, and combined them to produce this final image.

Star alignment tool

We used the software's astrophotography star alignment tool to merge an old colour DSLR image onto a high-resolution monochrome hydrogen alpha image of M42 to obtain an extremely pleasing result. It handles good-quality images well, but does tend to struggle to align some of the lower-quality images we selected for testing.



Planetary, lunar and solar image processing

Affinity Photo 2 performs extremely well for sharpening and handling different brightnesses in images. We found it excellent not only when used to process deep-sky objects, but also planetary, lunar and solar images. This enables astrophotographers to process a wide range of subject matter using the same package.

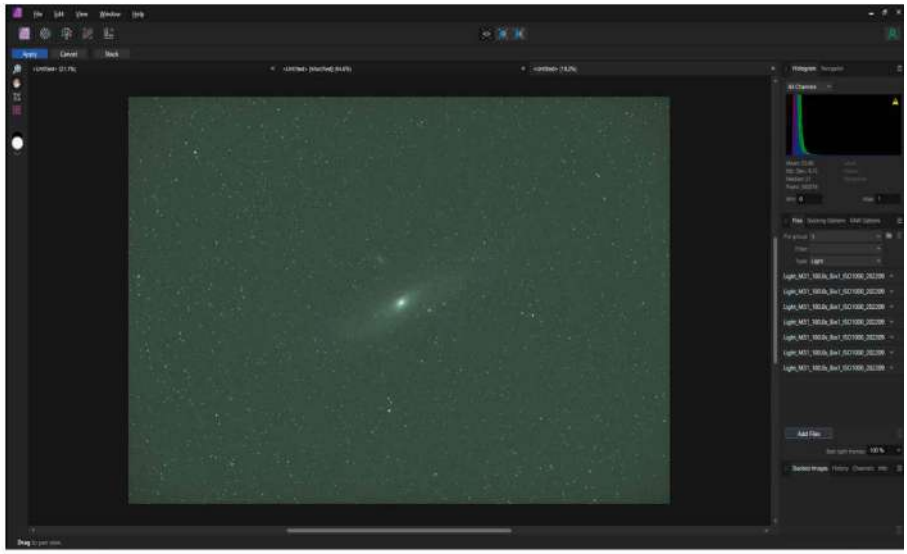
adjustment tools used to make changes to your images, including curves, levels, colour and so on.

There are five Affinity Persona icons at the top left, below the menu bar, but we only needed to use two during our test: the Photo Persona, where all the edits and adjustments are made to the images; and the Develop Persona, which is automatically activated when RAW image files are opened. Adjustments to images can be made here, if necessary, before opening within the Photo Persona for further editing.

We liked the way that the interface layout could be customised to suit the user. Tools can be made visible or hidden, and moved about. However, we found that the adjustment tools didn't allow us to rearrange them, nor are they arranged alphabetically. The lack of colour on the adjustment tools in the interface made it a little difficult initially to identify the tool we wanted, but this is a minor niggle.

All the adjustment tools worked very well, creating an adjustment layer nested within the image layer ▶

Stacking Persona



Affinity Photo 2 can stack one-shot colour, monochrome RAW and FITS camera images like its predecessor. Stacking can be set using mean, median and sigma clipping, depending on the data and intended result. Calibration frames like bias, darks, dark flats and flat frames can be added, helping improve the final stacked image.

When importing FITS files, the software automatically applies the appropriate Bayer pattern to the images. We stacked images from a DSLR, and dedicated one-shot colour and monochrome astronomy cameras to produce a variety of images. The usual star-shaped amp glow visible in sub-frames from the mono camera was effectively removed by adding dark frames. The stacking process does not include comet stacking and as far as we know, Serif has no plans to add this functionality, which is a shame. On some higher-spec machines, we experienced problems with slow performance, erratic functionality and strange rectangular 'holes' appearing on processed images. We found this was resolved by switching off hardware acceleration by clicking Preferences > Performance and unticking '*Hardware acceleration'.

KIT TO ADD

1. Astrophotography imaging kit

2. Powerful PC/Mac or laptop suited to graphics processing

3. Photo-quality inkjet printer

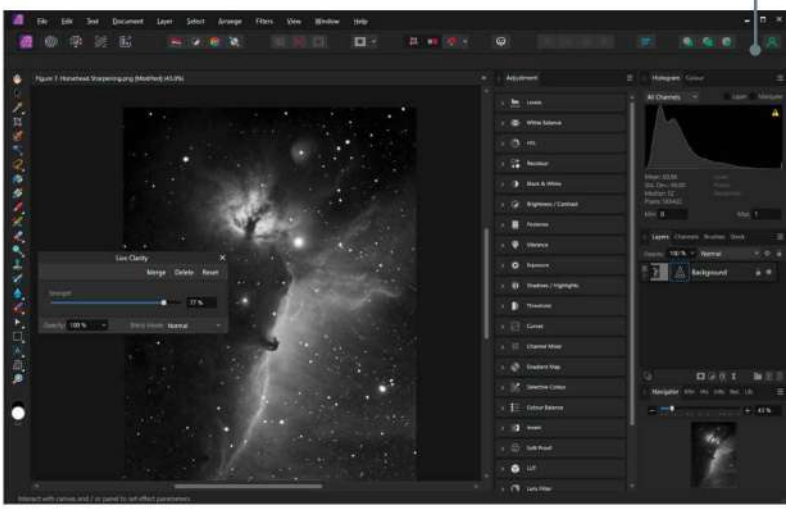
▶ being worked on, which is slightly different from the older version where adjustment layers sit above the selected layer. An annoying trait carried over from its predecessor is compressing TIFF files by default, which can cause quality problems if the saved file is further processed in other software.

An interesting feature is that several plugins designed for Adobe Photoshop also worked well with Affinity Photo 2, but we found that the success of running plugins depended on the computer's graphics card. Like its predecessor, Affinity Photo 2 can't use Photoshop actions, but you can create macros and save many pre-set adjustments and tool manipulations to automate processing steps.

Overall, Affinity Photo 2 is well thought out and extremely powerful, with a very attractive cost compared with rival image-processing software. Most of the newest features are either for everyday processing or behind-the-hood updates, possibly in anticipation of new features to be added later. Affinity Photo 2 could easily become your go-to photo editor as Serif does seem keen on adding features that are useful to astrophotographers.

Image sharpening

We processed several deep-sky objects using the 'Live clarity' sharpening tool. Using a hydrogen alpha stacked image of the Horsehead Nebula, it helped reveal much more detail within the nebula around the Horsehead and the subtle striations in the curtain behind the dark nebula.



VERDICT

Ease of use	★★★★½
Extras	★★★★½
Features	★★★★½
Functionality	★★★★★
Installation	★★★★★
OVERALL	★★★★½

ALL SCREENSHOTS: SERIF AFFINITY/DAVE EAGLE

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New astronomy and space titles reviewed

BOOKS

KEY SCIENCE

The One Thing You Need To Know

Marcus Chown
Michael O'Mara
£16.99 ● HB

Did you know that your stomach generates heat at a greater rate than a chunk of the Sun of the same size? Or that the brain is 10,000 times more energy-efficient than a supercomputer? I know I didn't!

The One Thing You Need To Know by Marcus Chown is a book for those curious about scientific concepts, but who were perhaps put off by the mind-boggling details of typical science books. Because to understand gravitational waves you first need to understand Einsteinian gravity in excruciating detail and be an expert in tensor calculus, right? Wrong!

Chown takes 21 concepts and cleverly starts with just one thing that you need to know to understand that topic, then shows how everything else that follows is a logical consequence. For instance, to understand special relativity, you need to know that light is uncatchable. This structural and thematic approach therefore makes the book accessible to just about every reader. On the whole, Chown does this very well, although perhaps not all of the topics in the book flow from just one idea. But what is equally fantastic about this book is that each chapter is bite-sized, taking only around 15 minutes to read. So, in this world where everyone is time-limited, you can get the idea of quantum theory while your dinner is cooking.

The main themes of the book are astronomy and physics topics, including quantum computers, black holes, the Higgs field and electricity. But it's refreshing that the author also discusses global warming, plate tectonics and human evolution. At first, these chapter titles may seem out of place among the other subjects covered, but Chown does a good job of making the narrative of the book flow. In addition to the science, he also discusses the people who've contributed to our knowledge of some of the subjects, along with cute facts that you will remember, such as today's sunlight was made at the height of the last Ice Age.

Today's sunlight was created during the Ice Age – just one of the things you need to know

This book will surely spark many people's interests in science by introducing them to an idea they can understand, be passionate about and pursue further. ★★★★★

***Laura Nuttall** is a Future Leaders Fellow at the University of Portsmouth*

ORLA/ISTOCK/GETTY IMAGES

Interview with the author

Marcus Chown

How did you select the book's topics?

I picked topics that were important but which also had something interesting and fun to write about. Global warming is important. But it was interesting for me because I got to write about Eunice Foote, who in 1856 discovered that carbon dioxide traps heat and was the first person in history to speculate that the climate would change if the amount of that gas in the atmosphere changed. She's been written out of history.

Which topic do we know least about?

The standard model of particle physics, describing how just three fundamental forces glue together three fundamental particles to create the world around us. But the theory does not tell us why the particles have the masses they have, why the forces have the strengths they have, or anything about the two things accounting for 95 per cent of the mass energy of the Universe: dark matter and dark energy. Only experiments and observations can change this, but so far we have had precious few clues!

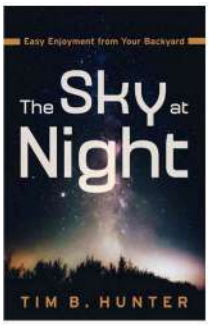
What scientific challenges lie ahead?

Science, since the Second World War, has become big science, which means finding the money to build bigger experiments on the ground and in space. Persuading taxpayers is hard, especially when what scientists are doing appears increasingly esoteric. But it's critical that the public and politicians understand science since many of the world's problems, such as global warming, can be appreciated only with a level of scientific education. That's why magazines such as this play an important role.

***Marcus Chown** is a science writer, journalist and broadcaster*

The Sky at Night

Tim Hunter
University of Arizona Press
£25.95 ● PB



Sometimes it seems there are as many guides to stargazing as there are stars in the sky. *The Sky at Night* (which has no connection to this magazine or the BBC series) takes us through the basics of amateur astronomy before dedicating chapters to the Moon, planets and stars, and advice on buying equipment. The book's unique selling point is its author is one of the founders of the International Dark Sky Association (IDA), as well as a dedicated amateur astronomer.

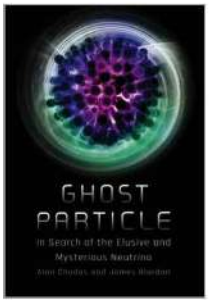
The informal and friendly tone is ideal for novices who may feel intimidated when faced with the vast night sky, and the diagrams are clear and nicely drawn. But given the emphasis is mostly on naked-eye observations, it would have been appropriate to include more practical advice on dark adaptation. Perhaps because the book started life as a weekly newspaper column, some of the information is repeated: we're told more than once about solar eclipses and Harvest Moons.

The author's candid account of how he approached writing a regular column is engaging and it would have been interesting to read more about his work setting up the IDA. The sections describing how the night sky appeared on key historical dates such as the D-Day landings are interesting, but the language used to describe some of these events gets platitudinous and wanders off the subject of astronomy. This is a short guide that covers a lot of ground – and stars – but it perhaps doesn't add much to a crowded market where there are already several very good guides. ★★☆☆☆

***Pippa Goldschmidt** is an astronomy and science writer*

Ghost Particle

Alan Chodos, James Riordon
MIT Press
£25 ● HB



Ghost Particle tells the story of the prediction, discovery and observation of one of the Universe's most elusive particles: the neutrino.

This is really a book about particle physics and seems to be aimed at someone who already has a grasp of basic physics. There are relatively simple explanations of some concepts and analogies abound, but the subject is so complex and (at times) subtle, that some basic familiarity is likely to be essential to avoid getting lost.

After an introductory overview, the book starts by covering the history of the neutrino. Somewhat oddly, the history is not purely chronological, but there's an organisation by 'topic'. While this perhaps simplifies having to flit between complex topics, it does mean keeping track can be a little difficult.

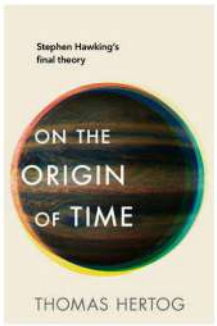
Later chapters focus on some of the more bizarre properties of neutrinos and, perhaps surprisingly, possible applications. By the subject's very nature there are a lot of names, dates and acronyms flying around (particle physicists are seemingly worse than astronomers when it comes to naming experiments!). It's not an easy or light read; the glossary is over 10 pages long, and some of the explanatory end-notes might have been more useful as footnotes.

Despite one of the authors being the grandson of the co-discoverer of the neutrino, there's very little in terms of personal stories focusing on the science and history. But if you know a little physics and want to know more about the neutrino, perhaps as a physics student or a keen consumer of popular science, then you'll glean a lot. ★★★☆☆

***Chris North** is Head of Public Engagement at Cardiff University School of Physics and Astronomy*

On the Origin of Time

Thomas Hertog
Torva
£20 ● HB



Any work staking a claim to the legacy of *A Brief History of Time* has big shoes to fill. Nevertheless this new book by Hawking's former doctoral student and collaborator Thomas Hertog comes complete with the bold subtitle 'Stephen Hawking's final theory'. And, fortunately, *On the Origin of Time* is more than up to the task.

Hertog sets out to tell the tale of a quest that has formed the bedrock of his own career and the final two decades of Hawking's: the search for an explanation of just how our remarkably life-friendly Universe came to arise from among the infinite possibilities embedded in the Big Bang. The result is a new theory of 'quantum cosmology' in which long-standing incompatibilities between gravity (described by Einstein's general relativity) and quantum physics (the fundamentally 'fuzzy' description of the subatomic realm) are apparently reconciled.

What's more, the theory boldly suggests that the laws and constants of nature were neither fixed by an unknown 'theory of everything' in the Big Bang itself, nor left unchained to play out in different configurations across the countless bubbles of a multiverse. Instead, Hertog and Hawking suggest that these rules and parameters developed along a sort of evolutionary pathway to become fixed by interactions on the largest scales and (to some extent) through the evidence we gather from the present-day Universe. The chain of discovery and reasoning that underlies all this is complex, but the clarity of Hertog's explanations, and a wealth of anecdotes from his work with Hawking, ensure one is rarely lost, and makes for a hugely rewarding read. ★★★★★

***Giles Sparrow** is a science writer and Royal Astronomical Society fellow*

Ezzy Pearson rounds up the latest astronomical accessories

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1 Monocular telescope building kit

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Specifically designed for visual observing nebulae, this filter lets through 90 per cent of the light from OIII and H-beta lines while cutting out other light, increasing the contrast around nebulae and reducing the effects of light pollution.

4 Bresser T2 extension tube set

Price £27 • **Supplier** The Widescreen Centre • **www.widescreen-centre.co.uk**

Get the separation exactly right when attaching your DSLR to your telescope with these extension tubes. The set comes with five tubes between 5mm and 30mm that have T2 threads on both sides and can be combined to achieve optimal focus.

5 Vixen XY guidescope mount

Price £200 • **Supplier** Telescope House • **www.telescopehouse.com**

Attach your guidescope to your main telescope with this mount. Capable of supporting up to 5kg, its position can be adjusted by plus or minus 6.5° in both horizontal and vertical directions.

6 MTB galaxy gloves

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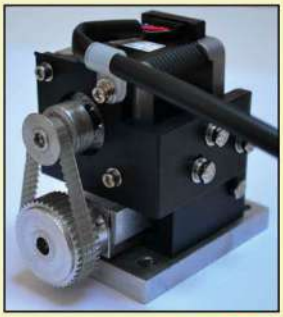

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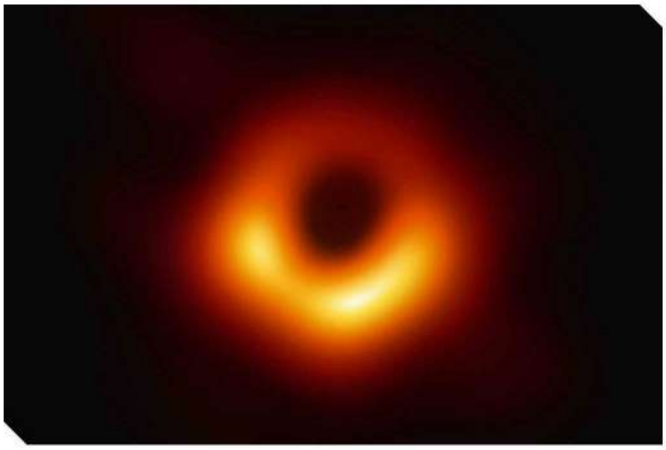
Ezzy Pearson interviews Luciano Rezzolla

Q&A WITH A BLACK HOLE PHYSICIST

The Event Horizon Telescope continues to test Einstein's general relativity predictions under the most extreme conditions

Why are black holes so difficult to study?
By definition, they cannot produce light, so they're elusive from that point of view. They are also the most compact objects that can be produced – if you could compress the Sun to a radius of about three kilometres, then you would produce a black hole. Because they are intrinsically compact and normally at very large distances, their projected size on the sky is extremely small, which is why it's so hard to see them.



▲ **A supermassive black hole in the centre of M87 and its shadow, captured by the EHT, an international network of radio telescopes, in 2019**

So how can we 'see' black holes?
We can see the light produced by material falling onto a black hole. As it falls, the material becomes denser because it will be confined to a smaller and smaller region. It becomes hotter and more energetic and will eventually start shining. So the light we see is from outside the black hole. Some of that is very close to the black hole, but manages to be emitted before entering.

How did the Event Horizon Telescope (EHT) help image black holes?
The EHT is not a telescope, but a collection of telescopes. Because black holes are so small on the sky, the only way to see them is using radio telescopes. When you work out what size you need, you realise you need a telescope a few thousand kilometres in size. You can't build a telescope that big, but what you can do is use a technique called radio interferometry to create a virtual telescope which is as large as the distance between the two small telescopes. The EHT's first observing run used a network of eight telescopes around the world – from Spain to Antarctica – to create a telescope the size of Earth. It took the first ever image of a black hole, located in the heart of M87, which we released in 2019.

What did that image show?
In the EHT image we see this funny-looking doughnut-shaped orange object. This is the light of a disc of plasma that's rotating around a black hole and is slowly being accreted before it actually enters – the accretion disc.

EHT COLLABORATION

Dr Luciano Rezzolla is chair of theoretical physics at Frankfurt University and a member of the executive board for the Event Horizon Telescope

How do we interpret those black hole images?
Before the image was produced, we were in charge of addressing the problem of what a black hole would look like. We performed a number of simulations. First, you try to understand what happens to matter falling onto a black hole – if you took a bucket of water and threw it in, how does it move? We actually use plasma endowed with strong magnetic fields, but that only teaches us what happens to matter. What we have to understand is what happens to the light this matter is also producing. It's a very complicated business in general relativity, because light can do very bizarre turns in a curved spacetime, so we have to calculate how the light actually reaches us. In this way, we can have a realistic view of the emission from this object.

What have we learned from these observations?
We have evidence that both M87 and our Milky Way have an object at the centre that looks and behaves like a black hole. We've shown that this object fits perfectly with the predictions of general relativity. That's a very important result, although maybe something everyone expected to see, but we've transformed the concept of black holes and event horizons into a testable object. To me, that is the most valuable contribution of the Event Horizon Telescope.

Will there be more runs of the EHT in the future?
There are many things which can improve. We are far from having the optimal resolution. You've seen our image – it's pretty fuzzy. Although the resolution window is the best possible, and a huge jump from what was done in the past, it's still not good enough for answering some of the questions I personally would like to answer. Is this really a black hole as Einstein predicted? Because there is still a lot of wiggle room for other interpretations. We made observing runs in 2018, 2021 and 2022 – the last of which added three new observatories, providing even more data – and we hope that the observations will continue to improve. It's going to be a long journey, to be able to answer some of these questions, but it's something we're actively doing right now.

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch a rare type of solar eclipse, an Emu on the horizon and the sights of the Southern Pleiades

When to use this chart

1 April at 00:00 AEDT (13:00 UT)
15 April at 23:00 AEST (13:00 UT)
30 April at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

APRIL HIGHLIGHTS

A rare hybrid solar eclipse occurs on 20 April. Starting out as an annular eclipse in the southern Indian Ocean, it then changes into a total before reaching the westernmost tip of Australia. The centre line will experience 60 seconds of totality at 11:30 WST. All states will see partial phases with maximum eclipse occurring in Perth at 11:21 obscured by 71%, Adelaide (13:30, 21%), Darwin (13:52, 81%), Melbourne (14:09, 11%), Sydney (14:29, 10%) and Brisbane (14:45, 16%) – all local times.

STARS AND CONSTELLATIONS

Aboriginal legends include many constellations but vary greatly across this large, isolating country. There are two recurring themes: one is the Emu sitting on the southeastern evening horizon. Made from dark nebulae, its head is the Coal Sack, near the Southern Cross, with its neck stretching down through the pointers, widening to the body in Scorpius and Sagittarius. The other is the Pleiades. The stories vary, but they all refer to seven sisters – talk about a universal concept!

THE PLANETS

Venus is the prominent beacon close to the northwest evening sky at the end of twilight. It spends April moving through Taurus, passing close to the Pleiades on 12 April. Mars, in Gemini, is nearby (upper right) moving slowly towards the stars of Castor and Pollux. The thin crescent Moon is below Venus on 23 April, visiting Mars three days later. Turning to the morning, Saturn arrives around 02:00 (mid-month) and is followed by Neptune two hours later.

DEEP-SKY OBJECTS

This month, a visit to Carina. The third-magnitude star Theta (θ) Carinae is the brightest member of IC 2602 (RA 10h 43m, dec. –64° 24'). This distinctive open cluster, the Southern Pleiades, has six fifth-magnitude stars within a 1° diameter circle. Like its northern namesake, binoculars reveal about 30 fainter stars. Around 0.5° south of Theta is another open cluster, Melotte 101. Although a bit challenging to find in such a busy star field, this tight (0.2° diameter) collection of faint (12th to 13th-magnitude) stars shows chains and clumps and is worth a visit. Note the fifth-magnitude star on its western edge.

Move 2.6° west of Theta to discover an impressive double star, HJ4306 (RA 10h 19.1m, dec. –64° 41'). It consists of matching white components of mag. +6.5 each, separated by only 2.1 arcseconds.

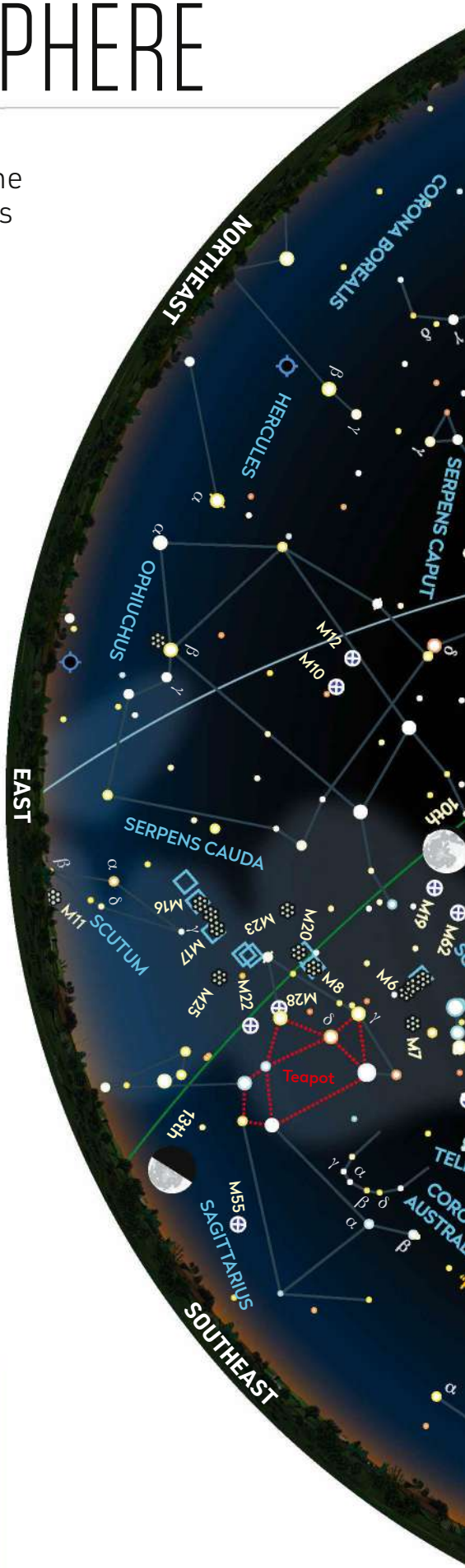

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE

NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
M51
M106
BOÖTES
CANES VENATICI
M63
M94
Cor Caroli
Kite
LYNX
LEO MINOR
COMA BERENICES
M3
Arcturus
M64
Sickle
Denebola
LEO
27th
1st
30th
M44
Regulus
Ecliptic
M87
M86
M84
M90
4th
M105
M96
VIRGO
CANCER
M5
CANIS MINOR
ORION
Procyon
Celestial Equator
7th
Spica
M104
CRATER
HYDRA
Alphard
CORVUS
M83
LIBRA
Ghost of Jupiter
M48
MONOCEROS
Winter Triangle
CENTAURUS
Cen A
M4
Antares
LUPUS
ANTLIA
PYXIS
M93
M47
VELA
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Coal Sack
Acrux
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M41
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IC 2602
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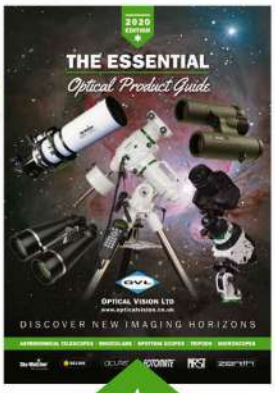

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